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AUTHOR	Phillips, Gary W.; And Others
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ABSTRACT

This report deals with a variety of ways that have been, or could be, used to interpret the scales used in the National Assessment of Educational Progress (NAEP). Policymakers, researchers, and other users of assessment results need to understand the methods used for reporting NAEP. Having a reference is particularly important as the methods of reporting are changing. Chapter 1 covers the following methods that have been used, or could be used, to interpret scales: (1) percentage correct for each item; (2) average percentage correct; (3) item mapping; (4) scale anchoring; (5) achievement levels; (6) using scoring rubrics; and (7) benchmarking. The contrast between anchor levels and achievement levels is discussed. Chapter 2 discusses the distinction between norm-referenced and criterion-referenced interpretations, and the validity of the inferences drawn from NAEP interpretations. Issues of validity are especially important with regard to achievement levels, because they represent an effort to go beyond describing, to prescribing recommended levels of achievement for the nation. Eleven figures and four tables present analysis data. An appendix provides exemplar exercises for scale anchoring and for achievement levels. (SLD)

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ED 361 396

NATIONAL CENTER FOR EDUCATION STATISTICS

INTERPRETING NAEP SCALES

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THE NATION'S REPORT CARD, the National Assessment of Educational Progress (NAEP), is the only nationally representative and continuing assessment of what America's students know and can do in various subject areas. Since 1969, assessments have been conducted periodically in reading, mathematics, science, writing, history/geography, and other fields. By making objective information on student performance available to policymakers at the national, state, and local levels, NAEP is an integral part of our nation's evaluation of the condition and progress of education. Only information related to academic achievement is collected under this program. NAEP guarantees the privacy of individual students and their families.

NAEP is a congressionally mandated project of the National Center for Education Statistics, the U.S. Department of Education. The Commissioner of Education Statistics is responsible, by law, for carrying out the NAEP project through competitive awards to qualified organizations. NAEP reports directly to the Commissioner, who is also responsible for providing continuing reviews, including validation studies and solicitation of public comment, on NAEP's conduct and usefulness.

In 1988, Congress created the National Assessment Governing Board (NAGB) to formulate policy guidelines for NAEP. The board is responsible for selecting the subject areas to be assessed, which may include adding to those specified by Congress; identifying appropriate achievement goals for each age and grade; developing assessment objectives; developing test specifications; designing the assessment methodology; developing guidelines and standards for data analysis and for reporting and disseminating results; developing standards and procedures for interstate, regional, and national comparisons; improving the form and use of the National Assessment; and ensuring that all items selected for use in the National Assessment are free from racial, cultural, gender, or regional bias.

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INTERPRETING NAEP SCALES

Gary W. Phillips • Ina V.S. Mullis
Mary Lyn Bourque • Paul L. Williams • Ronald K. Hambleton
Eugene H. Owen • Paul E. Barton

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OVERVIEW: THE ISSUES

This report deals with a variety of ways that have been, or could be, used to interpret the scales used in the National Assessment of Educational Progress (NAEP). NAEP is a congressionally mandated assessment survey that, under its current authorization (PL-100-297), is "placed in the National Center for Education Statistics" and reports "directly to the Commissioner for Educational Statistics." The Commissioner is to conduct the survey with the advice of the National Assessment Governing Board (NAGB), which will "formulate the policy guidelines for the National Assessment." Having such high visibility in a Federal statistical agency places demands on NAEP to be understandable to a wide range of audiences. In particular policymakers, researchers and other users of assessment results need to understand the methods used for reporting NAEP, or at least have a reference or set of guidelines that provide such an understanding. That is the primary purpose of this report.

Having a reference is particularly important when the methods of reporting are changing. Such a change is taking place now, in 1993, as the National Center for Education Statistics (NCES) begins to report NAEP results by achievement levels instead of the anchor levels that have been in place since 1984.[1] Other statistical agencies have dealt with changes in reporting methods by using both the old and new methods for a period of time. The purpose is to give the professional community and the public the opportunity to understand and accept the difference and provide time for researchers to evaluate the new approach. This is especially necessary when the old method is well established and accepted and the new approach is controversial and more visible.

The Census Bureau used this approach in changing its measure of poverty. When poverty levels were set in the early 1960s, there were few forms of noncash assistance received by poor people. As a result, such assistance was not considered as part of the definition of "income," which was then compared with the poverty thresholds to determine poverty status. However, during the next two decades the largest increase in low-income assistance has been in noncash programs, e.g., food stamps, Medicaid and

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[1]Achievement levels were reported in 1990 for the NAEP mathematics scale. However these reports were issued by the NAGB, not NCES (which is a Federal statistical agency).

housing subsidies. Since these benefits were not considered part of income, they had no effect on the poverty estimates released by the Census Bureau. There was much criticism of (1) this narrow income definition and (2) the exclusion of a large portion of assistance to low income people in the measurement of poverty. In the early 1980s the Census Bureau began an aggressive research program to confront this issue. It issued a series of technical reports providing alternative estimates and an ongoing discussion of measurement issues. As part of the process, a number of conferences were held and consensus building activities occurred. Although basic consensus now exists for how to measure these items, the 1990 estimates were still published in a "Research and Development" report. Current reports provide measures of alternative concepts of income, each of which has its uses. In the process new issues and controversies have arisen.

The Census Bureau change in the definition for reporting poverty in the 1980s is analogous to NCES's change in reporting student achievement in the 1990s. The old method of reporting on what students know and can do (anchor levels) is shifting to the new method of standards based reporting which emphasizes what students should know and should be able to do (achievement levels). The current report will help readers make the transition.

Chapter 1 covers methods in which NAEP either has used, or could use, to interpret its scales. The first two approaches are based on the percent correct for each item, four approaches involve the use of the 0-500 NAEP scale, and one approach uses the scoring rubric to derive the 0-400 NAEP writing scale. The seven methods are as follows:

1. Percentage Correct for Each Item - Used since the 1970s, these percentages are referred to as p-values and are computed by region, gender, size of community, education level of the parent, and race/ethnicity.

2. Average Percentage Correct - In the 1970s this scale served as NAEP's initial summary measure and was reported for sets of similar items.

3. Item Mapping - This approach was used in the 1985 literacy assessment of young adults. The procedure maps each test item on to the NAEP 0-500 scale.

4. Scale Anchoring - This approach was developed by ETS in 1984 as a method for describing selected points (standard deviation units) on the NAEP 0-500 scale. It describes what students know and can do at each of the anchor points (200, 250, 300, 350).

5. Achievement Levels - Developed by the NAGB in 1990 and 1992 this approach uses a judgmental procedure to set basic, proficient and advanced standards at grades 4, 8 and 12, and content descriptions of what students should know and be able to do at each level.

6. Using Scoring Rubrics - Developed for the 1984-1988 Writing Assessments, this method uses the unsatisfactory, minimal, adequate and elaborated levels of writing proficiency in the scoring rubrics as the NAEP scale.

7. Benchmarking - This is a potential way of interpreting the NAEP 0-500 scale by referencing the scores to some external standard such as performance on the Advanced Placement Test, the New Standards Project, the National Council of Teachers of Mathematics (NCTM) Standards, or the Pacesetters assessment.

One of the more important distinctions in Chapter 1 is the contrast between anchor levels and achievement levels. The following summarizes some of the major differences.

Contrasts Between Anchor Levels and Achievement Levels

Anchor Levels	Achievement Levels
• Describes in general what students know and can do.	• Describes in general what students should know and should be able to do.
• Descriptions have a cross-grade interpretation.	• Descriptions have a within-grade interpretation.
• Descriptions apply to four points on the NAEP scale (200, 250, 300, 350).	• Descriptions apply to nine ranges on the NAEP scale. (Basic, Proficient and Advanced by grade 4, 8 and 12).
• Descriptions are derived from an inspection of the items on the test.	• Descriptions are derived from the frameworks and the NAGB policy definitions.
• Four anchor points are determined through an empirical process (they are standard deviation units).	• Nine achievement levels are determined through a judgment (modified Angoff) process.
• Precision of the anchor levels is affected by measurement error.	• Precision of the achievement levels is affected by measurement error and judgment inconsistency.

Chapter 2 discusses two issues that are important in interpreting NAEP results. The first is the distinction between norm-referenced versus criterion-referenced interpretations, and how NAEP has attempted to provide both approaches to interpreting results. The second issue is the validity of the inferences from these interpretations. Validity is defined and is applied primarily to the anchor levels and the achievement levels. Issues of validity are important with all seven approaches to interpreting NAEP scales, but they are especially important with the use of achievement levels. This is because the achievement levels represent a more visible and controversial effort on the part of the National Assessment to go beyond describing, to the point of prescribing, recommended levels of achievement for the nation.

CHAPTER 1
WAYS OF INTERPRETING NAEP SCALES

Background

The National Assessment of Educational Progress was designed to provide comprehensive and dependable information on the progress of education in the United States.[2] For the curriculum areas assessed, NAEP measures progress in achievement on a periodic basis, profiles strengths and weaknesses in students' understanding, and describes the home, school, and classroom contexts for learning.

From the initial considerations of feasibility in 1963 to the first National Assessment in 1969 and over the years since then, NAEP has undergone a series of changes. NAEP has endeavored to reflect current information needs, as the many technological advances in measurement techniques during the last 30 years and the increasingly complex educational needs of the nation have continually changed the context for evaluating the meaning of "comprehensive and dependable" data.

Yet, while evolving within the context of changing times, the fundamental objectives of NAEP, as well as some of the general issues in implementation, have remained the same:

1. How can an appropriate set of objectives be developed?
2. What should the specifications be for the construction of new tests?
3. In what ways should the National Assessment results be reported?
4. How can these results be made meaningful?

The questions above were among those raised by John Gardner, then president of the Carnegie Corporation, to provide some structure for the deliberations at

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[2]Ralph W. Tyler, "Let's Clear the Air on Assessing Education," from *The Nation's Schools*, (Chicago, Il: McGraw-Hill, Inc., 1966).

the first conference on the feasibility of conducting a national assessment of education.[3] The essential goal of providing comprehensive and dependable data about educational achievement remains a vital concern, but today discussions revolve around how to **improve** the relevance of the data to be collected, the measurement methods involved, and the ways the data are analyzed and reported.

The original questions remain basic to guiding improvement and retain a freshness after years, but the environment for considering their answers has changed dramatically. Eight experts in statistics and educational measurement and six foundation members joined the U.S. Commissioner of Education, Francis Keppel, and his staff at that first national assessment meeting. Today, thousands of individuals across the country are involved in implementing and improving educational assessments. How best to measure educational progress is a topic of spirited national debates. Projects are underway to develop and implement national standards defining competent educational achievement, and a number of major efforts are being made to design "break the mold" assessments. Recently, the National Council on Education Standards and Testing recommended developing an entire system of assessments to monitor progress toward common standards, involving states and school districts as well as NAEP.[4]

Improving its approaches has been an historically intrinsic goal of those who have led and shaped NAEP. Since its inception, the descriptions of important learning within each curriculum area that define what NAEP should cover have been based on a consensus approach, involving educators, administrators, policymakers, and interested citizens. These descriptions, which began as lists of objectives established for each curriculum area, supported by worthwhile pieces of knowledge and skills classified under each objective, have evolved into integrated frameworks that address the increasing competencies needed for employability, personal development, and citizenship, and that account for contemporary research. Currently, discussions have begun about the possibility of aligning NAEP with the planned national education standards.

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[3]James A. Hazlett, "A History of the National Assessment of Educational Progress 1963 - 1973," (unpublished dissertation).

[4]The National Council on Education Standards and Testing, *Raising Standards For American Education*, (Washington, D.C.: U.S. Department of Education, 1992).

The assessment instruments developed to measure student achievement originally were comprised of discrete tasks, so the character of the response to a single question or activity task would be the basis for a judgment about student learning. This approach, which was modified during the late 1970s and 1980s in favor of more cost efficient and easily summarized questions, is now enjoying a resurgence in an updated form. Currently, performance tasks such as "hands-on" science investigations, are an important component of NAEP assessments in each curriculum area, and the assessment results are reported in terms of discrete tasks.

The NAEP analysis and reporting methods also have changed considerably since the inception of the project. Yet, providing the most relevant and useful data to the diverse NAEP audiences of policymakers, educators, and interested citizens remains a continual challenge. The questions about how to report NAEP results in meaningful ways, raised at the initial national assessment conference, are still pertinent 30 years later.

To provide background for continued exploration of the most effective strategies for reporting NAEP data to its numerous constituencies, this chapter presents information about ways NAEP data have been presented during the past 25 years. It also looks to the future, describing alternative ways to report and interpret results in the context of the national goals, emerging national standards, and increasingly more sophisticated measurement technology.

1. The Percentage Correct for Each Item

Because NAEP initially emphasized the importance of individual test questions having intrinsic merit, the first reports released by NAEP contained numerous individual test questions together with their respective "p-values." Essentially, a p-value is the percentage of the student population that answered the question correctly. P-values were computed by region, gender, size of community, education level of the parent, and race/ethnicity. This approach was in distinct contrast to tests that give each student a

score. However, NAEP's aim was not to describe individuals, but groups of students -- what proportion of them know this or can do that?[5]

The need to describe results for groups of students, rather than to score scores to individuals, has enabled NAEP to adopt a matrix sampling approach whereby students do not take the entire assessment in a curriculum area, but only a portion of it.[6] Results are obtained for all the questions in the assessment by sampling a number of nationally representative groups of students and giving each group part of the assessment. This reduces the burden for individual students and permits many more questions to be asked across different groups of students. Thus, NAEP has been able to collect data for hundreds of questions and provide a comprehensive picture of students' performance within each curriculum area.

The actual number of individual questions included in the early reports depended on the number of items in the assessment, and on how many of those were released to the public. In the first report for each curriculum area assessed, from 40 to 50 percent of all items assessed were released into the public domain. The unreleased items were kept secure for readministration in future assessments to measure trends. Because measuring trends requires that some portion of the measures be retained from assessment to assessment, maintaining security for part of the items from assessment to assessment continues to be an integral part of the NAEP design.

Percentages of correct responses to individual items provide very interesting information about educational achievement. The results from individual items can be used to highlight areas of strengths and weaknesses, or, viewed collectively, the results can be used to create an overall picture of achievement. As a brief illustration, scrutiny of the items contained in the 1992 mathematics assessment reveals that 89 percent of the fourth graders were able to multiply 3 by 405 and divide 108 by 9, when a calculator was provided. Seventy-two percent recognized that "three-hundred fifty-six thousand, ninety-seven" is 356,097. They also displayed beginning problem solving skills. Sixty-seven percent of the fourth graders recognized that if you had 50 hamburgers and 38 children, 12 could have

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[5]National Assessment of Educational Progress, *Report 1, 1969-1970 Science: National Results and Illustrations of Group Comparisons*, (Denver, CO: Education Commission of the States, 1970).

[6]Eugene G. Johnson, "The Design of the National Assessment of Educational Progress," *Journal of Educational Measurement*, 1992, 29, pp. 95-110.

two hamburgers. Forty-six percent were able to determine the amount of fencing needed when shown a figure of a rectangular garden 8 feet by 10 feet. Thirty-seven percent figured out that 10 pages in a photo album would be required for 88 photographs, if 9 pictures fit on a page. However, only 21 percent could calculate the amount of change that should be received from $10.00 if they bought two calculators for $3.29 each. The same percentage could determine how much flour was needed for three batches of cookies, if one batch needed 1 and 1/3 cups.

At grade 8, students demonstrated success with simple word problems. For example, 91 percent knew how much was charged per car if a car wash raised $84.00 and 21 cars were washed. They were less successful with multi-step problems and had difficulty communicating about mathematics. Sixty-three percent of the eighth graders explained in writing or by example how a number can be made smaller by multiplying, but only 13 percent were able to show their work and explain their reasoning involving a probability problem about combinations of coins. In working with geometric figures, 65 percent of the eighth graders could find the area of a rectangular carpet 9 feet long by 6 feet long, but only 29 percent could compute the area of a square when the radius of an inscribed circle was given. They also demonstrated varied performance on items measuring their understanding of numbers -- 51 percent recognized that 1/2 is close to 0.52, and 22 percent identified how many millions are in a billion.

At grade 12, students were able to solve traditional word problems in the context of real-life situations. For example, 88 percent determined the answer to a question about a checkbook balance, and two questions about the amount of change to be received were answered by 81 percent and 75 percent of the twelfth graders, respectively. More complex problems, however, were answered correctly by far fewer students. Only 5 percent could determine yearly costs of videotape rentals at two different stores, given information about charges, penalties, bonuses, and the number of tapes rented. In the content areas of geometry, statistics, and algebra, 40 percent could evaluate $6n + 15$ for $n = 1, 2$, and 3; 41 percent could find the slope of a line in the xy-plane, and 51 percent could determine the number of dead batteries from a sample. Thirty-one percent could compute an average from a frequency table, and 21 percent recognized the effect an outlier would have on the average of a distribution. Twenty-six percent could solve a system of equations, and 7 percent could find the degree measure of an angle in a pyramid.

Showing items along with their percentages correct is still an important way to report NAEP data. Most NAEP reports contain some examples of items to provide descriptive illustrations of summarized results, and the media as well as magazine articles often include example questions as part of their stories.

Still, the early mode of reporting many items together with their p-values highlighted a problem that persists today -- how to communicate a comprehensive view of NAEP findings in a brief and accurate manner. When reporting the first wave of assessments across curriculum areas, it became clear that for the most part, educators, policymakers, and the public did not have the time to study and assimilate the voluminous item-by-item results. The problem for NAEP audiences trying to understand the results became particularly acute when considering findings across a variety of subject areas.

In one effort to summarize p-values across curriculum areas, a 1977 report, "What Students Know and Can Do: Profiles of Three Age Groups," used the approach of classifying item-level results according to difficulty for 10 subject areas, and highlighting content area attainments.[7] After briefly describing performance in each subject area, by giving examples of the item-level results, the report highlighted achievements attained by many students (more than two-thirds), some students (approximately 33 percent to 67 percent), and only a few students (less than one-third). An application of using this approach to summarize the 1992 mathematics data is illustrated in Figure 1.1.

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[7]Ina V.S. Mullis, Susan J. Oldefendt, and Donald L. Phillips, *"What Students Know and Can Do: Profiles of Three Age Groups"* (Denver, CO: National Assessment of Educational Progress, 1977).

Figure 1.1

Summarizing p-Values: Selected Findings from NAEP's 1992 Mathematics Assessments — GRADE 4

Many fourth graders (more than two-thirds) can:

- Add and subtract two- and three-digit whole numbers when regrouping is required.
- Recognize numbers when they are written out.
- Identify instruments and units for measuring length and weight.
- Recognize simple shapes and patterns.

Some fourth graders (approximately 33% to 67%) can:

- Solve one-step word problems, including some division problems with remainders.
- Work with information in simple graphs, tables, and pictographs.
- Round numbers and recognize common fractions.
- Substitute a number for "□" in a simple number sentence.

Few fourth graders (less than one-third) can:

- Solve multistep word problems, even those requiring only addition and subtraction.
- Perform computations with fractions.
- Solve simple problems related to area, perimeter, or angles.
- Explain their reasoning through writing, giving examples, or drawing diagrams.

Figure 1.1

Summarizing p-Values: Selected Findings from NAEP's 1992 Mathematics Assessments (continued)

GRADE 8

Many eighth graders (more than two-thirds) can:

- Solve one-step word problems, involving all four basic operations.
- Use a ruler to measure in centimeters.
- Complete bar graphs and pictographs.
- Recognize the concept of variable in simple number sentences.

Some eighth graders (approximately 33% to 67%) can:

- Solve traditional multistep word problems.
- Calculate perimeter and area.
- Interpret tables and graphs.
- Provide an explanation based on a situation illustrating sample bias.
- Evaluate algebraic expressions when given the value of "x".

Few eighth graders (less than one-third) can:

- Apply properties of geometric figures to solve problems.
- Solve problems related to measures of central tendency (average, median, mode).
- Extend patterns to find a term.
- Explain their reasoning through writing, giving examples, or drawing diagrams.

Figure 1.1

Summarizing p-Values: Selected Findings from NAEP's 1992 Mathematics Assessments (continued)

GRADE 12

Many twelfth graders (more than two-thirds) can:

- Solve traditional multistep word problems.
- Read tables and a variety of graphic formats.
- Recognize properties of common geometric figures.

Some twelfth graders (approximately 33% to 67%) can:

- Perform operations with exponents.
- Apply an understanding of geometric relationships for common figures or solids (e.g., rectangles and cubes).
- Relate the information presented in tables to information in graphs.
- Solve simple linear equations.

Few twelfth grades (less than one-third) can:

- Apply an understanding of geometric relationships for less common figures or solids (e.g., pyramids).
- Demonstrate an understanding of the coordinate system in the xy-plane.
- Determine measures of central tendency from tables or graphs.
- Extend relatively complex patterns.
- Solve problems about functions.
- Explain their reasoning through writing, giving examples, or diagrams.

2. Average Percentage Correct

As the second wave of assessments was conducted in the 1970s and trend results became available, the need to report primarily by appropriate summary measures increased. NAEP needed a systematic and succinct way to respond to the basic question of whether performance in each curriculum area improved or declined.

After considerable deliberation, the Technical Advisory Committee (chaired by John Tukey at the time) decided that NAEP would adopt the average percentage correct across the items as its primary summary measure.[8] The advantage of averaging is that it tends to cancel out the effect of peculiarities in items that can affect item difficulty in unpredictable ways. Furthermore, averaging made it possible to compare the general performance of subpopulations using less complex computational methods, and this analysis was more easily understood by the public.

The reports on trends in performance across time from the first assessment to the second assessment in various subject areas used this method of reporting. The percentage correct was computed for each item, and these were averaged across sets of items to make comparisons across assessments or subpopulations of students. This method is not the same as the more usual procedure of counting the number right for each student, averaging across students, and then converting that number to a percent -- or even, since under the matrix sampling approach different students are given different sets of diverse items and, therefore, differing numbers of items, computing the percent of items correct for each student and taking the average across those students. Because the different sets of questions can be easier or more difficult, and NAEP's role has been to

[8]In the early years, the median had been used to make comparisons between the national performance and that of various demographic subgroups. But, the growing importance of the summary measure in reporting results led the Technical Advisory Committee to investigate the robustness of numerous measures of central tendency in view of their potential use in reporting NAEP data.

describe groups of students rather than individuals, the average percent-correct, as computed by NAEP, is the average of the item-by-item percent-correct statistics (p-values) across a set of items (for example, mathematic questions). Item-by-item p-values can be computed for students according to different demographic characteristics, for example, those in different regions of the country (southeast, northeast, etc.) and the average percent-correct compared across these groups of students.

Despite their advantages and continued use today in some situations, several problems with the average percent-correct statistics became apparent. For example, great care had to be taken in comparing across subsets of items within an assessment, because sets of easy or difficult items could make achievement appear to be overly high or low. Also, there was no way to make comparisons across age levels unless students were given the same set of items. An interest by NAEP audiences in comparing results across age levels led to a proliferation of results, because an average was computed for all the items given at an age group, as well as for the subsets of items that were in common across more than one age group (i.e., the items taken by 9- and 13-year-olds, the items taken by 13- and 17-year-olds, and the items taken by 9-, 13- and 17-year olds). [9]

In addition, data about trends in performance across time had to be based on the same set of items. Otherwise, there was no way to know if changes in the sets of items were in some way making the assessments easier or more difficult, and artificially influencing changes in overall achievement. The problem of not having a way to account for the effects of updating portions of the items from assessment to assessment led to cumbersome reporting for the third assessment in a curriculum area. Just for the national results at one age level, three types of overall results had to be presented -- trend for the items in all three assessments, trend for

[9]From 1969 to 1983 NAEP assessed students at ages 9, 13, and 17 but did not collect data from representative samples of students according to grade level. Because definitions of grade levels can change, age was felt to be a more stable basis for measuring trends. To provide information more useful to education decision-makers, in 1983 NAEP began collecting data for representative samples of students by grade as well as age. Currently, students are assessed at grades 4, 8, and 12.

the items in the last two assessments, and the average for all the items in the most recent assessment.[10]

Taken together, the various averages to compare across age levels and the various averages to compare across assessment years resulted in a very user unfriendly procedure for reporting trends. Furthermore, average percent-correct statistics have limitations from a measurement perspective. When each student is administered only a fraction of the items, as in the matrix-sampling approach used by NAEP, the average percentage correct provides no estimate of the distribution of proficiency in the population. This statistic describes the mean performance of students within subpopulations, but provides no other information about the distributions of skills among students in the subpopulations. Without some estimate of overall scores, there is no way to describe distributional performance patterns or levels for the best students or the worst students across the nation or within subpopulations.

Improving the Summary Measure: The NAEP Scales

Since 1983, NAEP has used response scaling methods to summarize results across items.[11] This analytic method overcomes the limitations inherent in the average percent-correct approach. If similar items require similar skills, the regularities observed in response patterns can often be exploited to characterize both respondents and items in terms of a relatively small number of variables. These variables capture the dominant features of the data, permitting NAEP to estimate proficiency for students based on a relatively small number of items.[12]

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[10] National Assessment of Educational Progress, *Three National Assessments of Science: Changes in Achievement, 1969-77* (Denver, CO: author, 1978).

[11] In general, NAEP uses response scaling methods in conjunction with an adaptation of matrix sampling where students are given interlocking subsets of items (called balanced incomplete block (BIB) spiralling). For a discussion of the introduction of scaling to NAEP, see Samuel Messick, Albert Beaton, and Frederick Lord, *A New Design for a New Era* (Princeton, NJ: Educational Testing Service, 1983).

[12] Albert E. Beaton and Eugene G. Johnson, "Overview of the Scaling Methodology Used in the National Assessment," *Journal of Educational Measurement*, 1992, Vol 29, pp. 163-175.

Robert J. Mislevy, Eugene G. Johnson, and Eiji Muraki, "Scaling Procedures in NAEP," *Journal of Educational Statistics*, 1992, 17, pp. 131-154.

All students can be placed on a common scale, even though none of the respondents take all of the items within the pool. Using the scale, it becomes possible to discuss distributions of proficiency for the nation and subgroups of students and to estimate the relationships between proficiency and a variety of background variables.

The advent of scaling NAEP data has steadily made the results more accessible to policymakers and the general public. A series of proficiency scales that span student performance across grades 4, 8, and 12 have been developed for the curriculum areas assessed. These scales range from 0 to 500, and they represent a summary measure of students' performance covering the domain specified in the objectives framework. Using average proficiency on the scale as a summary measure of student achievement or percentiles of performance to describe distributions, comparisons can be made across time and across groups of students using the same metric.

NAEP introduced new methods of creating composite scales from sets of scales, so that results can be reported for overall proficiency as well as domains of interest within curriculum areas. For example, there are mathematics scales for the content areas included in the mathematics objectives framework underlying the assessment -- numbers and operations; measurement; geometry; data analysis, statistics, and probability; and algebra and functions. The composite scale measuring overall mathematics performance is computed as the weighted average of the scale scores, where the weights correspond to the relative importance given to each content area as defined in the framework of objectives. Proficiency on the composite scale provides a global measure of performance for a curriculum area, while proficiency on the scales based on relevant subdivisions within that curriculum area provide more detailed information about performance.

The Need to Interpret the NAEP Scales

Comparisons among average proficiency results or performance percentiles on the NAEP scales provide easily accessible information about how educational achievement is changing across time, which groups of students are most and least proficient in particular curriculum areas, and relative strengths and

weaknesses across the content subdivisions within curriculum areas. This information, however, does not tell us what students know and can do within a curriculum area.

While providing numerous beneficial analytic capabilities beyond those provided by the item-by-item reporting initially used by NAEP, in and of themselves, the scales do not describe students' achievement in relation to the specifics covered in the assessment objectives frameworks.

To answer questions about students' strengths and weaknesses within particular content areas, additional analyses need to be conducted. For example, within the area of mathematics, each of the five content areas is comprised of various concepts, procedures, and problem-solving challenges. Many educators or parents may want to know, as described in the objectives framework, how much students understand about numbers (whole numbers, fractions, decimals, signed numbers, rational and irrational numbers, and numbers expressed in scientific notation), and if students can use particular operations (addition, subtraction, multiplication, division, powers, and roots). In particular, some NAEP audiences may be especially interested in students' ability to apply these mathematics concepts and procedures to solve problems.

Similarly, the measurement concepts assessed included length (perimeter and circumference), area and surface area, volume and capacity, weight and mass, angle measure, time, money, and temperature. Under geometry, students were asked to demonstrate knowledge of geometric figures and apply this information to establish geometric relationships and solve problems.

The data analysis, statistics, and probability questions covered appropriate methods for gathering data, the presentation of data, and the interpretation of data. Concepts included measures of central tendency, distributions, sampling, and probability. In algebra, the topics assessed were broad in scope, including algebra, elementary functions, trigonometry, and some topics from discrete mathematics.

There are ways to investigate students' performance on individual items in relation to their performance on the scales. The aim of these kinds of analyses is to provide descriptions of students' item-level performance in light of

their scale-score estimates. The method used is to investigate how well students at various levels on the scale did on the individual items. These interpretations, then, provide information about what the best students know and can do, in comparison to middle-performing and lower-performing students.

3. Item Mapping onto the NAEP Scales

One way to interpret the information obtained from individual items in relation to the NAEP scale is through an item mapping technique developed to report the results of NAEP's 1985 literacy assessment of young adults.[13] For each item in the assessment, the point on the scale was identified at which individuals with that level of proficiency had an 80 percent probability of responding correctly. That is, 80 percent of the individuals scoring at that scale level provided a correct response to the item.

Selected items were then identified for illustrative purposes, paraphrased, and graphically displayed along the scale. This information was provided in conjunction with examples of items in their entirety and data showing the percentages of students performing at or above various levels on the scale.

An adaptation of the item mapping procedure as applied to the 1992 mathematics results is portrayed in Figures 1.2 through 1.4. In these figures, the grade 4, 8, and 12 results are presented separately, and for each grade, progressively higher areas of the scale are mapped. Levels 150 through 300 are mapped for grade 4, Levels 200 through 350 for grade 8, and Levels 250 through 400 for grade 12. This approach focuses on the area of the scale where most students at each of the grades assessed performed, and thus permits more items to be shown on a single page. However, the properties of the NAEP mathematics scale would permit a condensed presentation where the area from 150 through 400 was mapped, and selected items from all three grades were shown (perhaps in different colors for the

[13]Irwin S. Kirsch and Ann Jungeblut, *Literacy: Profiles of America's Young Adults* (Princeton, NJ: Educational Testing Service, 1986).

different grades). Conversely, an expanded and more detailed application of this approach would include an item map for each of the five mathematics content areas for each of the three grades (e.g., one grade 4 map for numbers and operations, one for measurement, etc.).

The results in Figure 1.2 show that 98 percent of the fourth graders performed at or above Level 150 on the NAEP mathematics scale, 72 percent performed at or above Level 200, and 17 percent performed at or above Level 250. Virtually no fourth grade students performed at or above Level 300.

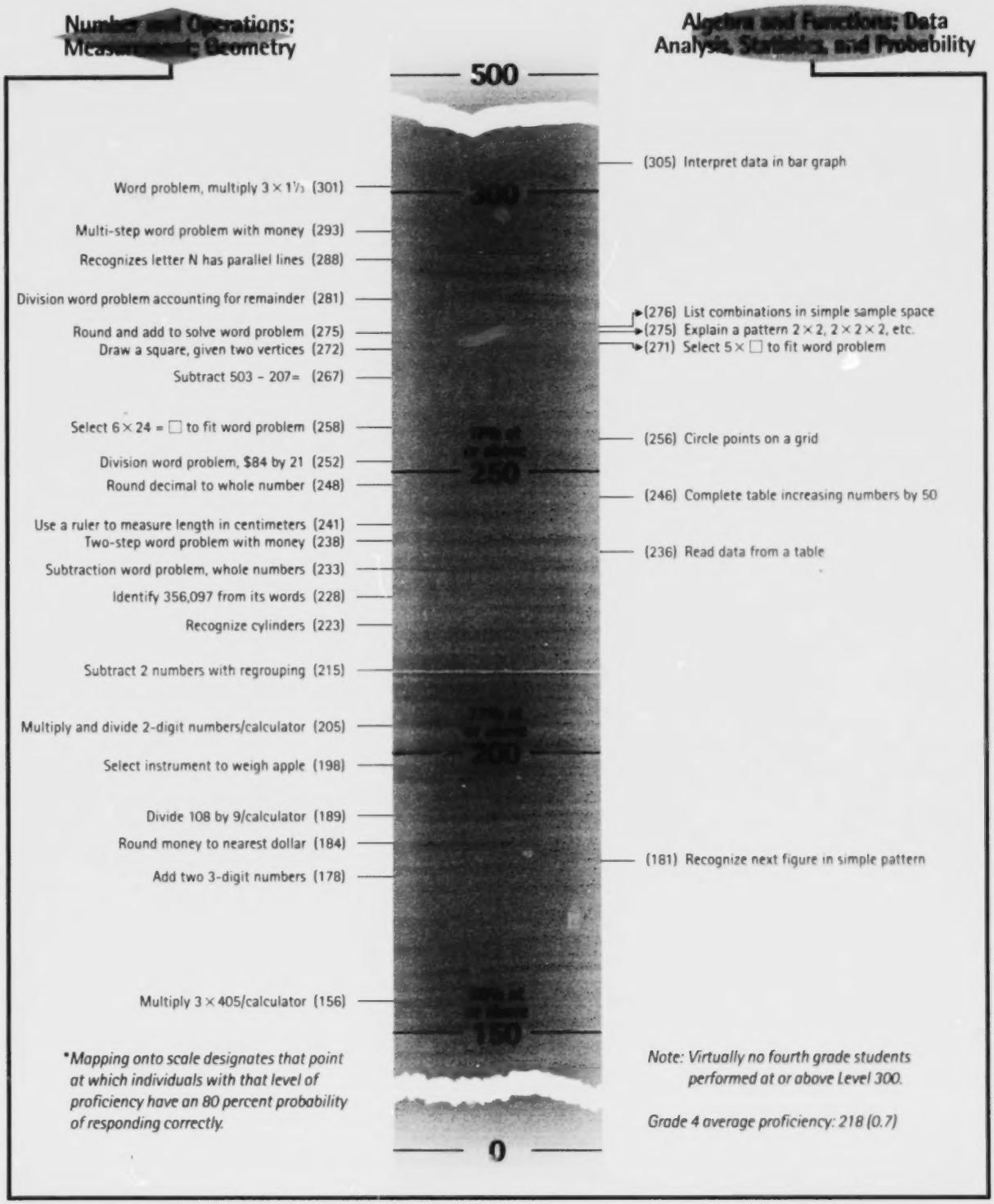
The items mapped on the left-hand side of the scale reflect items in the content areas of numbers and operations, measurement, and geometry. The fact that there are proportionally more items on the left hand side of the scale reflects the additional weight given those domains at grade 4 in the objectives framework.[14]

[14]For the 1990 and 1992 assessments, at grade 4, the approximate percentage distribution of questions by mathematical content area was 45 percent for numbers and operations, 20 percent for measurement, 15 percent for geometry, 10 percent for data analysis, statistics, and probability, and 10 percent for algebra and functions. At the other two grades assessed the weightings were as follows: numbers and operations, 30 percent at grade 8 and 25 percent at grade 12; measurement, 15 percent at grades 8 and 12; geometry, 20 percent at grades 8 and 12; data analysis, statistics, and probability, 15 percent at grades 8 and 12; and algebra and functions, 20 percent at grade 8 and 25 percent at grade 12.

Figure 1.2

Percentages of Students At or Above Points on the NAEP 1992 Mathematics Scale and Selected Tasks*

GRADE 4


Number and Operations; Measurement; Geometry
Algebra and Functions; Data Analysis, Statistics, and Probability
500
300
250
200
150
0
Word problem, multiply 3 × 1⅓ (301)
Multi-step word problem with money (293)
Recognizes letter N has parallel lines (288)
Division word problem accounting for remainder (281)
Round and add to solve word problem (275)
Draw a square, given two vertices (272)
Subtract 503 - 207= (267)
Select 6 × 24 = □ to fit word problem (258)
Division word problem, $84 by 21 (252)
Round decimal to whole number (248)
Use a ruler to measure length in centimeters (241)
Two-step word problem with money (238)
Subtraction word problem, whole numbers (233)
Identify 356,097 from its words (228)
Recognize cylinders (223)
Subtract 2 numbers with regrouping (215)
Multiply and divide 2-digit numbers/calculator (205)
Select instrument to weigh apple (198)
Divide 108 by 9/calculator (189)
Round money to nearest dollar (184)
Add two 3-digit numbers (178)
Multiply 3 × 405/calculator (156)
(305) Interpret data in bar graph
(276) List combinations in simple sample space
(275) Explain a pattern 2 × 2, 2 × 2 × 2, etc.
(271) Select 5 × □ to fit word problem
(256) Circle points on a grid
(246) Complete table increasing numbers by 50
(236) Read data from a table
(181) Recognize next figure in simple pattern

*Mapping onto scale designates that point at which individuals with that level of proficiency have an 80 percent probability of responding correctly.

Note: Virtually no fourth grade students performed at or above Level 300.

Grade 4 average proficiency: 218 (0.7)

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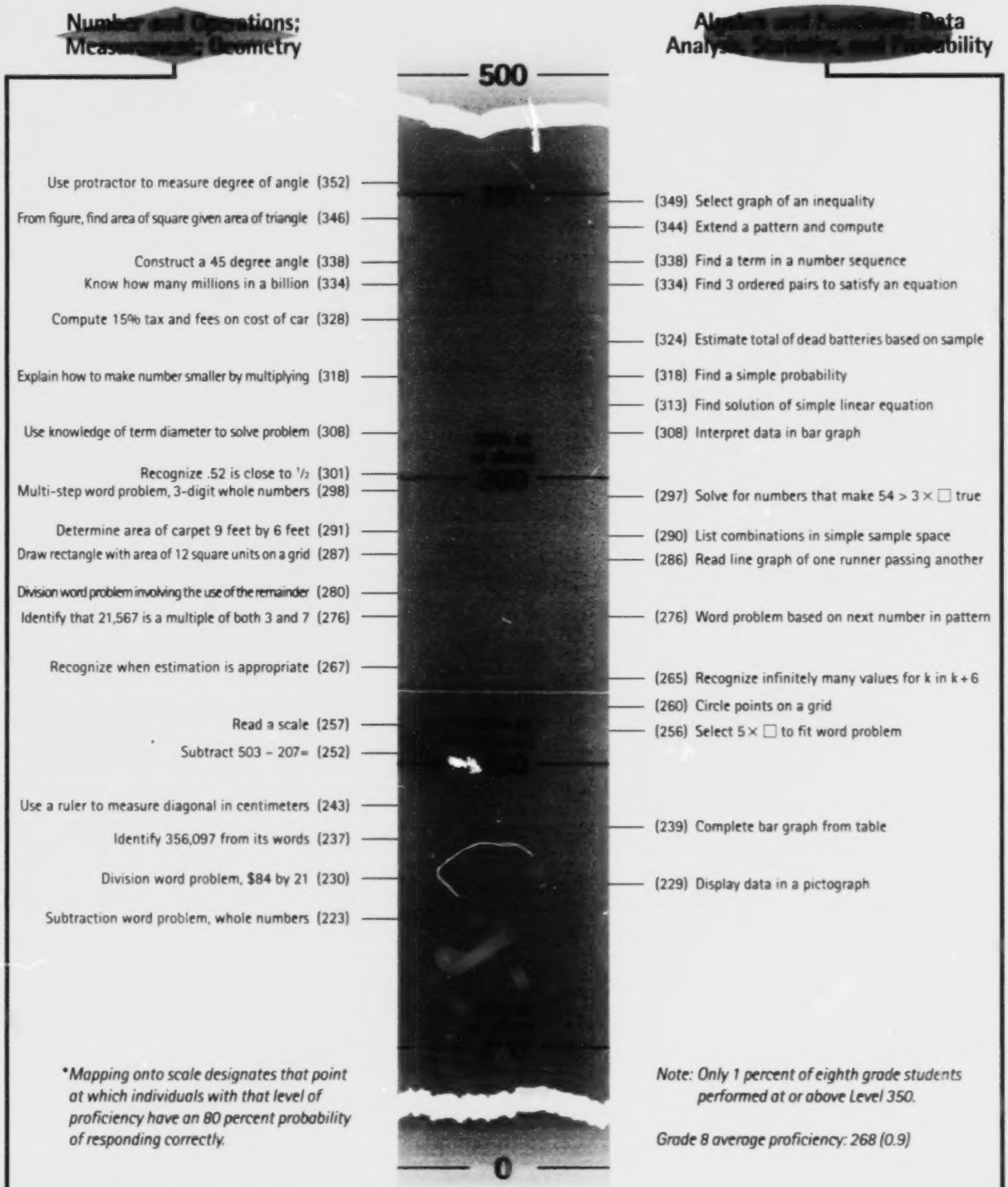
Figure 1.3

Percentages of Students At or Above Points on the NAEP 1992 Mathematics Scale and Selected Tasks*

GRADE 8


Number and Operations; Measurement; Geometry
Algebra and Functions; Data Analysis, Statistics, and Probability
500
300
0
Use protractor to measure degree of angle (352)
From figure, find area of square given area of triangle (346)
Construct a 45 degree angle (338)
Know how many millions in a billion (334)
Compute 15% tax and fees on cost of car (328)
Explain how to make number smaller by multiplying (318)
Use knowledge of term diameter to solve problem (308)
Recognize .52 is close to ½ (301)
Multi-step word problem, 3-digit whole numbers (298)
Determine area of carpet 9 feet by 6 feet (291)
Draw rectangle with area of 12 square units on a grid (287)
Division word problem involving the use of the remainder (280)
Identify that 21,567 is a multiple of both 3 and 7 (276)
Recognize when estimation is appropriate (267)
Read a scale (257)
Subtract 503 - 207= (252)
Use a ruler to measure diagonal in centimeters (243)
Identify 356,097 from its words (237)
Division word problem, $84 by 21 (230)
Subtraction word problem, whole numbers (223)
(349) Select graph of an inequality
(344) Extend a pattern and compute
(338) Find a term in a number sequence
(334) Find 3 ordered pairs to satisfy an equation
(324) Estimate total of dead batteries based on sample
(318) Find a simple probability
(313) Find solution of simple linear equation
(308) Interpret data in bar graph
(297) Solve for numbers that make 54 > 3 × □ true
(290) List combinations in simple sample space
(286) Read line graph of one runner passing another
(276) Word problem based on next number in pattern
(265) Recognize infinitely many values for k in k + 6
(260) Circle points on a grid
(256) Select 5 × □ to fit word problem
(239) Complete bar graph from table
(229) Display data in a pictograph

*Mapping onto scale designates that point at which individuals with that level of proficiency have an 80 percent probability of responding correctly.

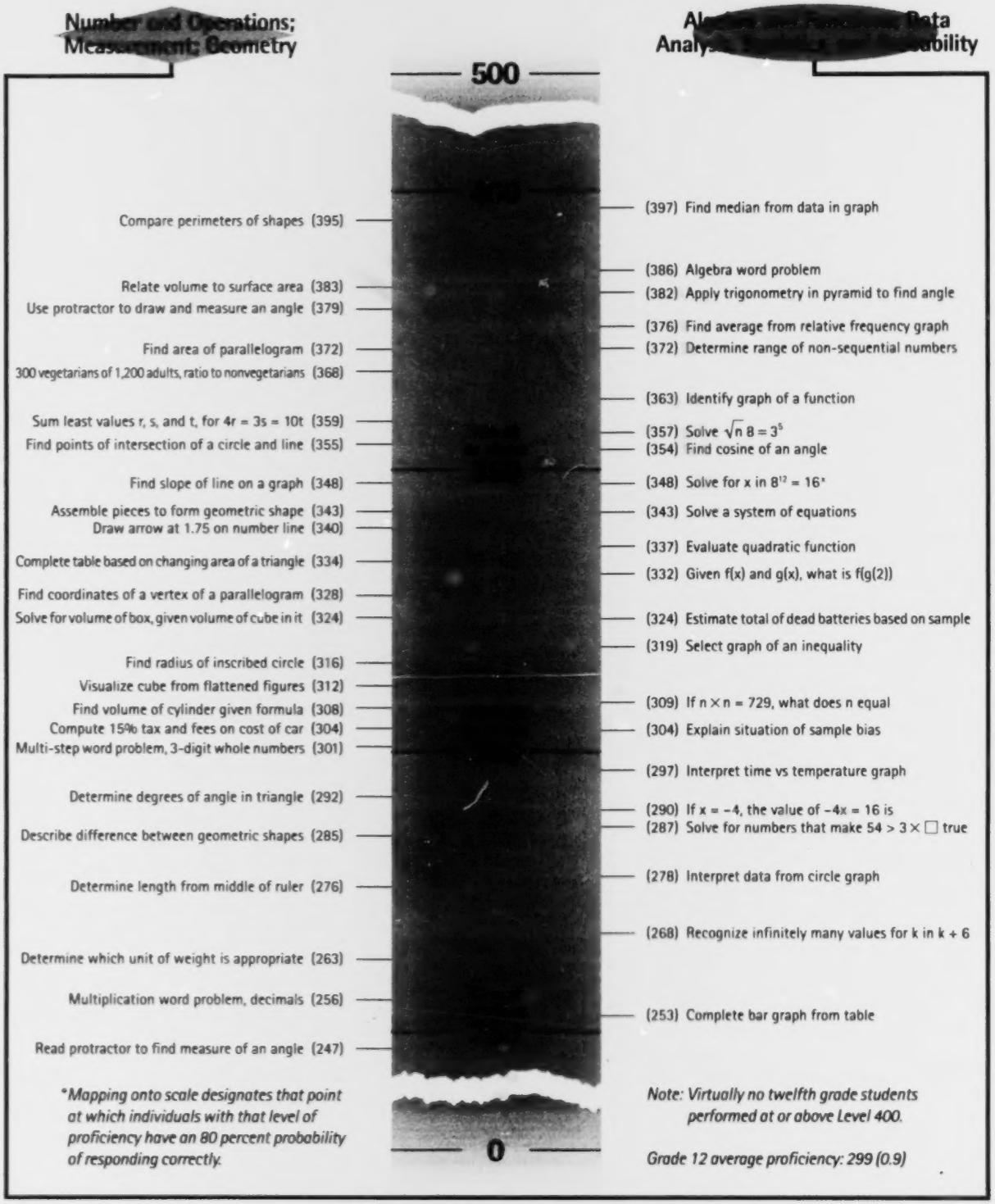
Note: Only 1 percent of eighth grade students performed at or above Level 350.

Grade 8 average proficiency: 268 (0.9)

Figure 1.4

Percentages of Students At or Above Points on the NAEP 1992 Mathematics Scale and Selected Tasks*

GRADE 12


Number and Operations; Measurement; Geometry
Algebra and Functions; Data Analysis; Probability
500
0
Compare perimeters of shapes (395)
Relate volume to surface area (383)
Use protractor to draw and measure an angle (379)
Find area of parallelogram (372)
300 vegetarians of 1,200 adults, ratio to nonvegetarians (368)
Sum least values r, s, and t, for 4r = 3s = 10t (359)
Find points of intersection of a circle and line (355)
Find slope of line on a graph (348)
Assemble pieces to form geometric shape (343)
Draw arrow at 1.75 on number line (340)
Complete table based on changing area of a triangle (334)
Find coordinates of a vertex of a parallelogram (328)
Solve for volume of box, given volume of cube in it (324)
Find radius of inscribed circle (316)
Visualize cube from flattened figures (312)
Find volume of cylinder given formula (308)
Compute 15% tax and fees on cost of car (304)
Multi-step word problem, 3-digit whole numbers (301)
Determine degrees of angle in triangle (292)
Describe difference between geometric shapes (285)
Determine length from middle of ruler (276)
Determine which unit of weight is appropriate (263)
Multiplication word problem, decimals (256)
Read protractor to find measure of an angle (247)
(397) Find median from data in graph
(386) Algebra word problem
(382) Apply trigonometry in pyramid to find angle
(376) Find average from relative frequency graph
(372) Determine range of non-sequential numbers
(363) Identify graph of a function
(357) Solve $\sqrt{n}\,8 = 3^5$
(354) Find cosine of an angle
(348) Solve for x in $8^{12} = 16^x$
(343) Solve a system of equations
(337) Evaluate quadratic function
(332) Given f(x) and g(x), what is f(g(2))
(324) Estimate total of dead batteries based on sample
(319) Select graph of an inequality
(309) If n × n = 729, what does n equal
(304) Explain situation of sample bias
(297) Interpret time vs temperature graph
(290) If x = −4, the value of −4x = 16 is
(287) Solve for numbers that make 54 > 3 × □ true
(278) Interpret data from circle graph
(268) Recognize infinitely many values for k in k + 6
(253) Complete bar graph from table

*Mapping onto scale designates that point at which individuals with that level of proficiency have an 80 percent probability of responding correctly.

Note: Virtually no twelfth grade students performed at or above Level 400.

Grade 12 average proficiency: 299 (0.9)

The items mapped on the right-hand side of the scale represent the areas of data analysis and algebra, where there were fewer assessment items and those that were included tended to cover introductory applications of concepts.

Nearly all fourth graders (98 percent) performed at Level 150 or higher. Those achieving at the lower end of the scale appeared to have a grasp of basic computation with whole numbers. For example, they could add (178) and demonstrated some understanding of rounding procedures (184). In contrast, the higher achieving fourth graders, the 17 percent who performed at or above Level 250 on the NAEP scale, provided correct solutions to word problems, such as selecting the number sentence (2 X 6 = □) to represent 2 rows of 6 cookies on a cookie sheet (258) or finding the answer to a division word problem with a remainder (281). They also circled points on a grid (256) and were able to list possible combinations in a simple sampling situation (276). Most of the handful of fourth graders performing at or above 300 on the scale were able to interpret data from a bar graph (305).

A comparison between Figure 1.2 and 1.3 indicates growth in mathematical understanding between grades 4 and 8. Nearly all eighth graders (97 percent) performed at or above Level 200 indicating that they were able to solve simple word problems using subtraction (223) and division (230). The one-fifth of eighth graders performing at or above Level 300 on the NAEP scale typically performed such tasks as explaining one way to make a number smaller by multiplying (318), computing a 15 percent charge for tax and fees on the cost of a car (328), and constructing a 45 degree angle (338). In data analysis and algebra, most were able to interpret data in a bar graph (308) and find the solution of a simple linear equation (313), respectively. Examples of somewhat more difficult tasks in these content areas were estimating the total number of dead batteries based on a sample (324) and selecting a graph for an inequality (349).

As shown in Figure 1.4, half the twelfth graders performed at or above level 300, demonstrating some understanding of geometry, data analysis, and algebra. Most were able to calculate how the area of a triangle would change and provide their results in tabular form (334). A more difficult task for these students was solving an equation using exponents (348). The top-performing twelfth graders

(6 percent attaining Level 350) had a high degree of success in finding the coordinate points where a circle and line intersected (355) and determining the ratio of vegetarians to nonvegetarians, if 300 out of 1,200 adults were vegetarians (368). They demonstrated understanding of geometric relationships by relating volume to surface area (383) and comparing perimeters of shapes (395). They had somewhat more difficulty in finding an average from a graph of relative frequency (376) and applying trigonometry to find the degree measure of an angle in a pyramid (382).

To help us understand the properties of analyses which relate item-level performance to performance on the overall scale, it is helpful to review the two types of percentages involved in item mapping and what they mean:

- **The percentage performing at or above a particular point on the scale.** This is the percentage of students whose overall scale-score estimate was at that level or higher. For example, 17 percent of the fourth graders performed at Level 250 or higher.

- **The 80 percent criteria for mapping.** On the map, 80 percent of the students with that scale-score estimate answered the item correctly. Or, because the model places both students and items on the scale, students with that score estimate are predicted to have an 80 percent chance of success in answering that item or items like it correctly. To give a concrete example, 80 percent of the fourth graders with a score estimate of 252 were able to solve a simple division word problem about how much was charged per car at a car wash, if 21 cars were washed and $84.00 was collected. Thus, a student with a scale score of 252 would have an 80 percent probability of answering this question correctly. As an extension, this student would have a high probability of answering other questions similar to the car wash question correctly (around 80 percent).

Care should be taken in interpreting the item mapping results to keep the meaning of these percentages in mind. Taken together, 17 percent of the students scored at or above 250, and for those who scored at 252, 80 percent answered the car wash problem correctly. It must be emphasized, however, that these data reflect probabilities of success based on the performance observed in the assessment for students at various levels on the scale. In reality, although 80 percent of the fourth graders scoring at 252 answered the car wash problem correctly, even greater percentages of the students at higher levels on the scale answered the question correctly. Also, some (but proportionally fewer) students at

lower levels on the scale answered the item correctly (and most fourth graders were at lower levels on the scale). The probabilities of success on this item are less for students at lower levels of the scale -- much less at the lowest levels. Still, some of them did answer the item correctly. Therefore, it is not a correct interpretation of the results that only the 17 percent of students performing at or above 250 could answer the car wash item correctly. In fact, across all students, regardless of their scale-score estimate, 58 percent responded correctly to the car wash item.

Looking at items at the lower end of the scale, it is also important to remember that although almost all students at the higher end of the scale would answer the item correctly, not all of them would. To illustrate, 98 percent of the fourth graders performed at or above 150 on the scale. Also, 80 percent of those scoring at 156 were able to multiple 3 by 405, when a calculator was available. Thus, the probabilities based on the assessment results indicate that nearly all fourth graders would be able to solve this problem. In actuality, the p-value was 89 percent.

Considering that even knowledgeable adults are likely to make careless errors or misread questions and, therefore, 100 percent of them would not answer items correctly, 80 percent is considered a high rate of success on the NAEP assessment. Also, for items that map at the lower ranges of an interval, nearly all students at the higher ranges of the interval generally answer the item correctly. Using the 80 percent probability criteria suggests that in most situations, students with the scale-score indicated would solve the problem correctly. However, the item mapping procedure can be implemented using different criteria for success on the items. For example, an analysis based on a 50 percent probability of success could be used to indicate emerging skills for fourth graders who performed at various levels on the scale.

In summary, the item mapping technique, as implemented by NAEP, describes the types of questions students scoring at particular levels on the scale are likely to answer correctly (with an 80 percent probability of success). It is a useful way of profiling results across the range of the scale and is very versatile, as any set of items for any group of students who participated in the assessment can be mapped onto the scale. Also, this method is based almost entirely on an empirical

process. With the exception of specifying the level of the probability of success for the analysis and creating the item descriptions, the process of creating the maps is free of subjective or judgmental steps.

However, it is important to remember that for data about how many students in the population answered an item correctly, regardless of their overall performance on the scale, the percentage correct (p-value) is still the appropriate statistic.

4. Scale Anchoring

Scale anchoring is a procedure to characterize students' performance at particular points or "anchor levels" on the scale. As implemented for the 1990 and 1992 mathematics assessments, NAEP's scale anchoring procedure was based on comparing item-level performance by students at four levels on the 0 to 500 mathematics composite scale -- Levels 200, 250, 300, and 350.[15] In brief, the analyses delineated four sets of about 50 anchor items each that discriminated between adjacent performance levels on the scale.[16]; The four sets of empirically derived anchor items were studied by panels of mathematics educators who carefully considered and articulated the types of knowledge, skills, and reasoning abilities that were demonstrated by correct responses to the items in each set. These descriptions, together with example anchor items, were then used in conjunction with the

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[15]Ina V.S. Mullis, John A. Dossey, Eugene H. Owen, and Gary W. Phillips, *The State of Mathematics Achievement, NAEP's 1990 Assessment of the Nation and the Trial Assessment of the States* (Washington, D.C.: U.S. Department of Education, 1991).

Ina V.S. Mullis, John A. Dossey, Eugene H. Owen, and Gary W. Phillips, *The 1992 Mathematics Report Card* (Washington, D.C.: U.S. Department of Education, 1993).

Albert E. Beaton and Nancy L. Allen, "Interpreting Scales through Scale Anchoring," *Journal of Educational Statistics*, 1992, 17, pp. 191-204.

[16]In 1992, 22 items anchored at Level 200 and another 8 almost anchored (also considered, since they nearly satisfied the anchoring criteria), at Level 250 there were 45 anchor items and 27 that almost anchored, at Level 300 there were 59 anchor items and 29 that almost anchored, and at Level 350 there were 43 items and 34 that almost anchored. Of the 432 items included in the process, 165 did not anchor. In 1990, the totals of anchored and almost anchored items were: 43 at Level 200, 46 at Level 250, 64 at Level 300, and 43 at Level 350. Of the 275 items used in the process, 79 did not anchor.

percentages of students performing at or above the four levels to convey a concise interpretation of the scale results.

To provide a sufficient pool of respondents at each anchor level for the analyses, students performing at Level 200 on the scale were more broadly defined as those whose estimated mathematics proficiency was between 187.5 and 212.5, students at 250 were defined as those with estimated proficiency between 237.5 and 262.5, those at 300 had estimated proficiencies between 287.5 and 312.5, and those at 350 between 337.5 and 362.5. In theory, anchor levels above 350 or below 200 could have been described; however, so few students in the assessment performed at the extreme ends of the scale that it was not possible to do so.

After identifying the fourth, eighth, and twelfth graders performing at the four anchor levels on the scale, two kinds of information were computed for these students for each item -- the actual number of students at each of the levels included in the analysis and the percentage who answered the item correctly (weighted in accordance with the sampling design). Thus, for each item, a p-value is computed separately for the students performing at each anchor level (four p-values for each item, as shown later in this section). These analyses were performed for each grade level at which the item was administered, and for the grade levels combined, if the item was administered at more than one grade level.

Based on the p-values for each anchor level, the following criteria were used to identify the items that discriminated between scale levels. That is, the items that students at one anchor level were more likely to answer correctly than were students at the next lower level.

Because it was the lowest level being defined, Level 200 was not analyzed in terms of the next lower level, but was examined for the percentage of students at that level answering the item correctly. More specifically, for an item to anchor at Level 200:

1) At least 65 percent of the students at Level 200 answered the item correctly.

2) At least 100 students were available for the analysis.

The first criterion was established so that items associated with a level were those for which students at that level would have demonstrated at least some

degree of success (at least 65 percent or about two-thirds), and therefore, those above the level would have an even higher degree of success. The second criterion provides stability for the p-value estimates.

For an item to anchor at the remaining levels, additional criteria had to be met. For example, to anchor at Level 250:

1) Sixty-five percent or more of the students at Level 250 answered the item correctly.

2) At least 30 percent fewer students at Level 200 than at Level 250 answered the item correctly.

3) At least 50 percent of the students at Level 200 answered the item incorrectly.

4) At least 100 students at both Levels 200 and 250 were available for the analysis.

The same principles were used to identify anchor items at Levels 300 and 350. The additional criteria was attempting to find items fairly likely to be answered correctly by students at one level, but unlikely at the levels below. Essentially, for any given anchor item, students at the anchor level are likely to answer the question correctly (65 percent or more likely), while those at the next lower level are less likely to answer the question correctly (at least 30 percent less likely). Also, students at the next lower level are somewhat likely to get the item wrong (at least half of them). Collectively, as identified through this procedure, the mathematics items at each anchor level represented advances in students' understandings from one level to the next -- mathematical topics providing items students at that level were more likely to answer correctly than were students at the next lower level.

In preparation for use by panelists, the items were assembled with their full anchoring documentation and scoring guides (for open-ended items) and placed in notebooks by anchor level order concluding with the "did not anchor" items. Within each anchor level, the items were arranged in accordance with the classifications contained in the objectives framework. From 15 to 20 panelists, representing mathematicians; mathematics educators at the college, secondary, and elementary levels; and state and district mathematics supervisors, met for three days

to identify systematically the mathematical knowledge, understanding, and problem-solving abilities demonstrated by the students answering each item correctly. These descriptions were then summarized to develop the characterizations of performance for each anchor level. After being briefed in the anchoring process and given their assignment, panelists worked independently in two groups to analyze the items, draft their descriptions of performance for each anchor level, and select illustrative items to support their descriptions. On the third day, panelists and staff worked together as a whole to combine the two independently derived sets of descriptions.

Each of the two times this process was used, both groups agreed that the two drafts were very similar. However, the cross-validation process was helpful and permitted more individuals to be involved in the process. It also should be noted that although the 1992 assessment was designed to measure trends from 1990, the anchoring process was conducted to update the descriptions to reflect some evolution in the 1992 items. Some items in the 1992 assessment had been carried forward from 1990, but others were newly developed measures of the mathematics framework intended to reflect improvements in assessing mathematics achievement. Therefore, as anticipated, the 1992 descriptions were very similar to the 1990 descriptions, but there were variations.

Table 1.1 presents trends in the average mathematics proficiency for fourth, eighth, and twelfth graders between the 1990 and 1992 NAEP assessments and the percentages of students in each grade performing at or above the four anchor levels. The descriptions summarizing performance at the four anchor levels are found in Figure 1.5.

Table 1.1 National Overall Average Mathematics Proficiency and Anchor Levels, Grades 4, 8, and 12

		Assessment Years	Grade 4	Grade 8	Grade 12
Average Proficiency		1992	218(0.7)>	268(0.9)>	299(0.9)>
		1990	213(0.9)	263(1.3)	294(1.1)
Level	Descrirtion		Percentage of Students at or Above		
200	Addition and Substraction, and Simple Problem Solving with Whole Numbers	1992	72(0.9)>	97(0.4)	100(0.1)
		1990	67(1.4)	95(0.7)	100(0.2)
250	Multiplication and Division, Simple Measurement, and Two-Step Problem Solving	1992	17(0.8)>	68(1.0)	91(0.5)>
		1990	12(1.1)	65(1.4)	88(0.9)
300	Reasoning and Problem-Solving Involving Fractions, Decimals, Percents, and Elementary Concepts in Geometry, Statistics, and Algebra	1992	0(0.1)	20(0.9)>	50(1.2)>
		1990	0(0.1)	15(1.0)	45.(1.4)
350	Reasoning and Problem Solving Involving Geometric Relationships, Algebra, and Functions	1992	0(-)	1(0.2)	6(0.5)
		1990	0(-)	0(0.2)	5(0.8)

>The value for 1992 was significantly higher than the value for 1990 at about the 95 percent confidence level. <The value for 1992 was significantly lower than the value for 1990 at about the 95 percent confidence level. The standard errors of the estimated percentages and proficiencies appear in parentheses. It can be said with 95 percent certainty that for each population of interest, the value for the population is within plus or minus two standard errors of the sample. When the proportion of students is either 0 percent or 100 percent, the standard error is inestimable (-). However, percentages 99.5 percent and greater were rounded to 100 percent and percentages 0.5 percent or less were rounded to 0 percent.

Figure 1.5

Description of Mathematics Proficiency at Four Anchor Levels on the NAEP Scale

Level 200	Addition and Subtraction, and Simple Problem Solving with Whole Numbers

Students at this level can identify solutions to one-step word problems, involving addition or subtraction. They can add and subtract whole numbers in most situations, and when a calculator is available, they can multiply and divide. They are able to select the largest whole number from a set of numbers in the thousands, and can match the verbal and symbolic names for numbers.

Students demonstrated familiarity with length and weight, by selecting appropriate instruments and units to measure these attributes. They are able to recognize some basic properties of two-dimensional geometric figures as well as the names of standard examples of these figures. They can extend simple patterns.

Level 250	Multiplication and Division, Simple Measurement, and Two-Step Problem Solving

When presented with a problem situation, students at this level have some understanding of the problem, can identify extraneous information, and have some knowledge of when to use computational estimation. They have an understanding of addition, subtraction, multiplication, and division with whole numbers. They can solve simple two-step problems involving whole numbers. They are able to round whole numbers and solve simple word problems involving place value, estimation, and multiples.

Students can use a ruler to measure length in centimeters and have some understanding of area and perimeter. They can solve simple problems using readings from instruments. They demonstrate a knowledge of properties of triangles, squares, rectangles, circles, and cubes. They can solve problems that require visualizing, drawing or manipulating simple geometric shapes. They are able to complete bar graphs and pictographs, as well as use information from graphs or tables to solve simple problems. They can recognize simple number patterns, are beginning to deal informally with the idea of a variable, and have some knowledge of simple probability.

Level 300	Reasoning and Problem-Solving Involving Fractions, Decimals, Percents, and Elementary Concepts in Geometry, Statistics, and Algebra

Students at this level can use various strategies and explain their reasoning in a variety of problem solving situations. They are able to solve problems involving not only whole numbers but with decimals and fractions. They can represent and find equivalent fractions, and use these concepts in solving routine problems. They can find a percent of a number and use this skill in simple problems. Multiplication and division of whole numbers have developed to the extent that students can use all four operations in multi-step problems.

Students can read and use instruments in more complex situations. They can find areas of rectangles, recognize relationships among common units of measure, and solve routine problems involving similar triangles and scale drawings. They have knowledge of definitions and properties of simple geometric figures in the plane. Their spatial sense includes the ability to visualize a cube in either three-space or its flattened form in a plane.

Students can calculate averages, select and interpret data from a variety of graphs, list the possible arrangements in a sample space, find the probability of a simple event, and have a beginning understanding of sample bias. They can use knowledge of relative frequencies in simple simulation situations. Students show the ability to evaluate simple expressions and solve linear equations. Students can graph points on coordinate axes, locate the missing coordinates for a corner of a square, and identify which ordered pairs satisfy a given linear equation.

Level 350	Reasoning and Problem Solving Involving Geometric Relationships, Algebra, and Functions

Students at this level can reason and estimate with percents. They can recognize scientific notation and find the decimal equivalent. They can apply their knowledge of area and perimeter of simple geometric figures to solve problems. They can find the circumferences of circles and the surface areas of solid figures. They can solve for the length of missing segments in more complex similarity situations. Students can apply the Pythagorean Theorem to find the hypotenuse of a right triangle. They are beginning to use rectangular coordinates in problem solving situations and can apply geometric properties and relationships in solving problems.

Students can compute means from frequency tables and create a sample space to determine probabilities, and read the graph of a step-function. Students can use exponents and evaluate expressions given in functional notation. In number theory, they have an understanding of even and odd numbers and their properties. They can identify an equation describing a linear relation provided in a table, and solve literal equations and systems of two linear equations. They have some knowledge of trigonometric relations. These students can represent and interpret complex patterns and data using numbers, expressions, and graphs. Given the graph of a function they can identify its zeros and the effect on the graph of taking the absolute value of the function.

At grade 4, the percentage of students performing at or above Level 200 rose from 1990 to 1992, indicating an increase in the proportion of fourth graders able to identify solutions to one-step word problems involving addition or subtraction. There was also an increase in the percentage of fourth graders (from 12 to 17 percent) who could use multiplication and division in the context of two-step problem-solving (Level 250). Probably because material covered at Level 300 does not typically occur in the curriculum until later than fourth grade, only a handful of fourth graders reached this level.

Virtually all of the eighth graders performed at or above Level 200 in both assessments. Similarly, about two-thirds of these students performed at or above Level 250 in both assessments, indicating little change across time in eighth graders' ability to use multiplicative reasoning or compute with whole numbers using all four numerical operations. However, the percentage of students performing at or above Level 300, typified by some mathematical understanding of geometry, data analysis, and algebra, increased between 1990 and 1992, from 15 to 20 percent.

Most twelfth graders in both assessments performed at or above Level 250, indicating some facility in two-step problem solving. That one-half demonstrated success with problems involving fractions, decimals, percents, and elementary algebra, represented an improvement from 1990, when only 45 percent performed at or above Level 300. However, only 6 percent demonstrated a breadth of mathematical understanding that included problem-solving involving geometric and algebraic relationships, and this represented virtually no change from 1990.

In summary, the scale anchoring process, as implemented by NAEP, can provide a concise summary of what students know and can do at various points along the scale that differentiates them from students performing at lower levels. The procedure involves both an empirical component to identify the anchor items and a subjective process to develop the descriptions. However, two cross-validation efforts and the use of the process in the 1990 and 1992 mathematics assessments have indicated a high degree of similarity between descriptions developed by different groups of panelists. The process has been implemented for all three grade levels simultaneously to maximize the amount of information available from the scale and to condense the presentation of the results. However, as shown, the anchor level information is created for each grade level and panelists could consider the three sets of data separately, devising separate descriptions for

each grade. In general, there are many exemplar items for each anchor level; however, for illustrative purposes, one exemplar item for each of the anchor levels is presented in the appendix.

5. Achievement Levels

The 1988 legislation reauthorizing the National Assessment of Educational Progress created an independent board, the National Assessment Governing Board, responsible for setting policy for the NAEP program.[17] Among other responsibilities, the board has a statutory mandate to identify "appropriate achievement goals for each...grade in each subject area to be tested under the National Assessment." Consistent with this directive, and striving to achieve one of the primary mandates of the statute "to improve the form and use of NAEP results," the Board set performance standards (called achievement levels by NAGB) on the National Assessment in 1990, and again in 1992. NAGB established a set of standards in 1990 for the mathematics assessment. Due to technical difficulties they were re-established in 1992 with an improved methodology. The discussion in this report is limited to the approach used in 1992.

Differences between anchor levels and achievement levels

In contrast to anchor levels which describe actual student performance on NAEP, achievement levels are performance standards on the NAEP assessment that identify what students should know and be able to do at various points along the proficiency scale. In developing threshold values (cut scores) for the levels, a broadly constituted panel of judges rated each grade-specific NAEP item pool using operationalized policy definitions developed by the Board for "Basic," "Proficient," and "Advanced" student performance. In contrast, the numerical values for anchor levels represent selected points at regular intervals on the scale that have a statistical meaning in describing the distribution of scores.

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[17] Public Law 100-297. (1988). National Assessment of Educational Progress Improvement Act (Article No. USC 1221). Washington, DC.

Another difference between the two is that the achievement levels provide grade-specific interpretations of expected performance, while the proficiency levels offer a cross-grade interpretation of the NAEP scale. There are three achievement levels, Basic, Proficient, and Advanced for each of the three grades assessed, 4, 8, and 12. Each of the nine levels is accompanied by a content description and exemplar exercises that delineate recommended grade-appropriate expectations for student performance. This is in contrast to the cross-grade descriptions of overall average proficiency at the four anchor levels described in an earlier section of this report.

The 1992 level-setting activity

In September 1991, NAGB let a contract to American College Testing (ACT) to convene panels of judges that would recommend levels on the 1992 NAEP assessments in reading, writing, and mathematics. The work of ACT involved hundreds of professionals and members of the general public who assisted in the planning, designing, and implementing of the level-setting meetings and public hearings.[18] Moreover, the ACT documents were widely disseminated to a number of stakeholder groups for comment before the work was initiated.

While the 1992 level-setting activities are not unlike those undertaken by the Board for 1990, significant improvements were made in the process for 1992. There was a concerted effort to bring greater technical expertise to the process: the contractor selected by the Board has a national reputation for setting standards in a large number of certification and licensure exams; an internal and external advisory team monitored all the technical decisions made by the contractor throughout the process; and State assessment directors periodically provided their expertise and technical assistance at key stages in the project.

Three important sets of outcomes resulted from the standard-setting activities. The first set of outcomes was the operationalized descriptions of each of the three levels of expected achievement, by content area, for each of the three grades. The second set of outcomes was the scale scores defining the lower bound for each achievement level. The third set of outcomes was the selection of exemplar assessment exercises taken

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[18]American College Testing. (1992). *Design document for setting achievement levels on the 1992 National Assessment of Educational Progress in mathematics, reading, and writing: Final version*. Iowa City, IA: Author.

from the NAEP item pool that would facilitate in describing the substance of each of the levels. One illustrative item for each achievement level is provided in the appendix. Taken together, these three sets of outcomes constitute a new way of interpreting the achievement of students on the NAEP scale.

Policy-Based and Operationalized Definitions

Before the standard-setting panels reviewed the exercise pool and the exemplar responses for the extended constructed response questions, it was necessary to operationalize the policy definitions of the three achievement levels, Basic, Proficient, and Advanced. The policy-based definitions of Basic, Proficient and Advanced were as follows:

- ***Basic***. *This level, below proficient, denotes partial mastery of knowledge and skills that are fundamental for proficient work at each grade--4, 8, and 12.* For twelfth grade, this is higher than minimum competency skills (which normally are taught in elementary and junior high schools) and covers significant elements of standard high-school-level work.

- ***Proficient***. *This central level represents solid academic performance for each grade tested--4, 8, and 12. It reflects a consensus that students reaching this level have demonstrated competency over challenging subject matter and are well prepared for the next level of schooling.* At grade 12, the proficient level encompasses a body of subject-matter knowledge and analytical skills, of cultural literacy and insight, that all high school graduates should have for democratic citizenship, responsible adulthood, and productive work.

- ***Advanced***. *This higher level signifies superior performance beyond proficient grade-level mastery at grades 4, 8, and 12.* For twelfth grade, the advanced level shows readiness for rigorous college courses, advanced technical training, or employment requiring advanced academic achievement. As data become available, it may be based in part on international comparisons of academic achievement and may also be related to Advanced Placement and other college placement exams.

These policy definitions were presented to panelists along with an illustrative framework for more in-depth development and operationalization of the levels. The panelists were asked to describe the three levels from the specific NAEP assessment framework with respect to the content and skills to be assessed. The operationalized definitions were refined throughout the level-setting process, as well as validated with a supplementary group of judges subsequent to the level-setting meetings. Panelists were also asked to develop a list of illustrative tasks associated with each of the levels, after which sample items or exemplar papers, in the case of extended constructed response items, from the NAEP item pool were identified to exemplify the full range of performance of the intervals between levels.

Since the purpose of the operationalized descriptions was to use such descriptions as a common mental construct through which to filter the rating of items, the emphasis in operationalizing the definitions was on the performance of examinees in the basic, proficient, and advanced regions of the scale. In other words, the operationalized descriptions and the exemplar items needed to represent the full range of performance from one level to the next higher level with an emphasis on typical performance for the range.

The descriptions of levels generated by panelists were originally developed by separate grade-level-specific groups, and as such, varied in the sharpness of the language, the degree of specificity of the statements, and even in format. Therefore, an important task of a subsequent validation effort was to sharpen the language, and, in the case of mathematics, to give the descriptions durability by reflecting the language of the National Council of Teachers of Mathematics Standards.[19] The ratings, however, were based on the descriptions developed by the first panel of judges. The operationalized descriptions for grades 4, 8, and 12 are contained in Figures 1.6, 1.7 and 1.8, respectively.

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[19]National Council of Teachers of Mathematics. Commission on Standards for School Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Washington, DC: NCTM.

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Figure 1.6

Description of Mathematics Achievement Levels for Basic, Advanced, and Proficient Fourth Graders

The five NAEP content areas are (1) numbers and operations, (2) measurement, (3) geometry, (4) data analysis, statistics, and probability, and (5) algebra and functions. At the fourth grade level, algebra and functions are treated in informal and exploratory ways, often through the study of patterns. Skills are cumulative across levels—from Basic to Proficient to Advanced.

Basic 211	**Fourth grade students performing at the basic level should show some evidence of understanding the mathematical concepts and procedures in the five NAEP content areas.**

Fourth graders performing at the basic level should be able to estimate and use basic facts to perform simple computations with whole numbers; show some understanding of fractions and decimals; and solve some simple real-world problems in all NAEP content areas. Students at this level should be able to use - though not always accurately - four-function calculators, rulers, and geometric shapes. Their written responses are often minimal and presented without supporting information.

Proficient 248	**Fourth grade students performing at the proficient level should consistently apply integrated procedural knowledge and conceptual understanding to problem solving in the five NAEP content areas.**

Fourth graders performing at the proficient level should be able to use whole numbers to estimate, compute, and determine whether results are reasonable. They should have a conceptual understanding of fractions and decimals; be able to solve real-world problems in all NAEP content areas; and use four-function calculators, rulers, and geometric shapes appropriately. Students performing at the proficient level should employ problem-solving strategies such as identifying and using appropriate information. Their written solutions should be organized and presented both with supporting information and explanations of how they were achieved.

Advanced 280	**Fourth grade students performing at the advanced level should apply integrated procedural knowledge and conceptual understanding to problem solving in the five NAEP content areas.**

Fourth graders performing at the advanced level should be able to solve complex and nonroutine real-world problems in all NAEP content areas. They should display mastery in the use of four-function calculators, rulers, and geometric shapes. These students are expected to draw logical conclusions and justify answers and solution processes by explaining why, as well as how, they were achieved. They should go beyond the obvious in their interpretations and be able to communicate their thoughts clearly and concisely.

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Figure 1.7

Description of Mathematics Achievement Levels for Basic, Advanced, and Proficient Eighth Graders

The five NAEP content areas are (1) numbers and operations, (2) measurement, (3) geometry, (4) data analysis, statistics, and probability, and (5) algebra functions. Skills are cumulative across levels—from Basic to Proficient to Advanced.

Basic 256	**Eighth grade students performing at the basic level should exhibit evidence of conceptual and procedural understanding in the five NAEP content areas. This level of performance signifies an understanding of arithmetic operations—including estimation—on whole numbers, decimals, fractions, and percents.**

Eighth graders performing at the basic level should complete problems correctly with the help of structural prompts such as diagrams, charts, and graphs. They should be able to solve problems in all NAEP content areas through the appropriate selection and use of strategies and technological tools - including calculators, computers, and geometric shapes. Students at this level also should be able to use fundamental algebraic and informal geometric concepts in problem solving.

As they approach the proficient level, students at the basic level should be able to determine which of available data are necessary and sufficient for correct solutions and use them in problem solving. However, these 8th graders show limited skill in communicating mathematically.

Proficient 294	**Eighth grade students performing at the proficient level should apply mathematical concepts and procedures consistently to complex problems in the five NAEP content areas.**

Eighth graders performing at the proficient level should be able to conjecture, defend their ideas, and give supporting examples. They should understand the connections between fractions, percents, decimals, and other mathematical topics such as algebra and functions. Students at this level are expected to have a thorough understanding of basic-

level arithmetic operations - an understanding sufficient for problem solving in practical situations.

Quantity and spatial relationships in problem solving and reasoning should be familiar to them, and they should be able to convey underlying reasoning skills beyond the level of arithmetic. They should be able to compare and contrast mathematical ideas and generate their own examples. These students should make inferences from data and graphs; apply properties of informal geometry; and accurately use the tools of technology. Students at this level should understand the process of gathering and organizing data and be able to calculate, evaluate, and communicate results within the domain of statistics and probability.

Advanced 331	**Eighth grade students performing at the advanced level should be able to reach beyond the recognition, identification, and application of mathematical rules in order to generalize and synthesize concepts and principles in the five NAEP content areas.**

Eighth graders performing at the advanced level should be able to probe examples and counter examples in order to shape generalizations from which they can develop models. Eighth graders performing at the advanced level should use number sense and geometric awareness to consider the reasonableness of an answer. They are expected to use abstract thinking to create unique problem-solving techniques and explain the reasoning processes underlying their conclusions.

Figure 1.8

Description of Mathematics Achievement Levels for Basic, Advanced, and Proficient Twelfth Graders

The five NAEP content areas are (1) numbers and operations, (2) measurement, (3) geometry, (4) data analysis, statistics, and probability, and (5) algebra functions. Skills are cumulative across levels—from Basic to Proficient to Advanced.

Basic 287	**Twelfth grade students performing at the basic level should demonstrate procedural and conceptual knowledge in solving problems in the five NAEP content areas.**

Twelfth grade students performing at the basic level should be able to use estimation to verify solutions and determine the reasonableness of results as applied to real-world problems. They are expected to use algebraic and geometric reasoning strategies to solve problems. Twelfth graders performing at the basic level should recognize relationships presented in verbal, algebraic, tabular, and graphical forms; and demonstrate knowledge of geometric relationships and corresponding measurement skills.

They should be able to apply statistical reasoning in the organizations and display of data and in reading tables and graphs. They also should be able to generalize from patterns and examples in the areas of algebra, geometry, and statistics. At this level, they should use correct mathematical language and symbols to communicate mathematical relationships and reasoning processes; and use calculators appropriately to solve problems.

Proficient 334	**Twelfth grade students performing at the proficient level should consistently integrate mathematical concepts and procedures to the solutions of more complex problems in the five NAEP content areas.**

Twelfth grade students performing at the proficient level should demonstrate an understanding of algebraic, statistical, and geometric and spatial reasoning. They should be able to perform algebraic operations involving polynomials; justify geometric relationships; and judge and defend the reasonableness of answers as applied to real-world situations. These students should be able to analyze and interpret data in tabular and

graphical form; understand and use elements of the function concept in symbolic, graphical, and tabular form; and make conjectures, defend ideas, and give supporting examples.

Advanced 366	**Twelfth grade students performing at the advanced level should consistently demonstrate the integration of procedural and conceptual knowledge and the synthesis of ideas in the five NAEP content areas. areas.**

Twelfth grade students performing at the advanced level should understand the function concept; and be able to compare and apply the numeric, algebraic, and graphical properties of functions. They should apply their knowledge of algebra, geometry, and statistics to solve problems in more advanced areas of continuous and discrete mathematics.

They should able to formulate generalizations and create models through probing examples and counter examples. They should be able to communicate their mathematical reasoning through the clear, concise, and correct use of mathematical symbolism and logical thinking.

Cut-scores

A modified Angoff procedure was used to establish the cut-scores for each grade level.[20] Each judge rated about one-half the exercises at a given grade-level using an iterative procedure. The round 1 ratings were completed by each judge independently, having the benefit of the policy definitions and the agreed-upon operationalized descriptions. In round 2, judges were given within-group consistency feedback as well as the percentage of students correctly answering the items based on the results of the field testing conducted in 1991.[21] For round 3, judges additionally were given within-judge consistency feedback and were encouraged to discuss their ratings with other members of their grade-level group.[22] The expected p-values from the judges' round 3 ratings were aggregated across the item pool (taking into account the various weightings of the subscales) and averaged across judges to derive the final cut scores in the percent-correct metric. Since for every percent-correct score there is a corresponding NAEP composite scale score, the percent-correct scores for each level could now be mapped onto the NAEP scale to derive the threshold values in the scale score metric.

In rating the items, judges were asked to think of the marginally advanced, marginally proficient, and marginally basic student. In this manner, the lower bounds for the three levels were set by the panel. However, the descriptions of the levels and the exemplar items refer to the entire range of performance between two levels. For example, the proficient description and exemplar items refers to the range of scores at and above the lower bound for the proficient level and below the lower bound for advanced.

There were a number of reasons why the Board accepted the cut scores recommended by the standard-setting panels. The process used to derive the standards was substantially more complex than that used in other standard-setting situations; the panels were broadly constituted and reflected the best professional judgment of a representative group; the resulting standards were widely disseminated for comment prior to approval;

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[20]Angoff, W.H (1971). Scales, norms, and equivalent scores. In R.L. Thorndike (Ed.), *Educational measurement* (2nd ed., pp. 508-600. (Washington, DC: American Council on Education).

[21]Friedman, C.B. & Ho, K.T. (1990, April). *Interjudge consensus and intrajudge consistency: Is it possible to have both in standard-setting?* Paper presented at the annual meeting of NCME, Boston, MA.

[22]Fitzpatrick, A.R. (1989). Social influences in standard-setting: the effects of social interaction group judgements. *Review of Educational Research*, 59, 315-328.

and finally, the recommended standards seemed reasonable and credible to the Board. Still, the data showed that there was not unanimity among the judges, and such variability in the ratings was cause for concern. In its final action, Board members believed that some moderation of the cut scores was in order and directed, for reporting purposes, that the first standard error below the mean of the judges' ratings would be used to estimate the percent of students at or above the levels. Table 1.2 summarizes the recommended levels and the adopted levels at one standard error below the mean, and the national overall performance at each achievement level is presented in Table 1.3.

TABLE 1.2 Recommended and Adopted National Mathematics Achievement Levels

	Basic	Proficient	Advanced
Grade 4			
Recommended	213	252	284
Adopted	211	248	280
Grade 8			
Recommended	259	300	336
Adopted	256	294	331
Grade 12			
Recommended	291	335	367
Adopted	287	334	366

TABLE 1.3 National Mathematics Achievement Levels, Percent of Students At or Above, Grades 4, 8, and 12

Grade	Assessment Years	Basic	Proficient	Advanced
4	1992	61(1.0)>	18(1.0)>	2(0.3)
	1990	54(1.4)	13(1.1)	1(0.4)
8	1992	63(1.1)>	25(1.0)>	4(0.4)
	1990	58(1.4)	20(1.1)	2(0.4)
12	1992	64(1.2)>	16(0.9)	2(0.3)
	1990	59(1.5)	13(1.0)	2(0.3)

>The value for 1992 was significantly higher than the value for 1990 at about the 95 percent confidence level. < The value for 1992 was significantly lower than the value for 1990 at about the 95 percent confidence level. The standard errors of the estimated percentages and proficiencies appear in parentheses. It can be said with 95 percent confidence for each population of interest, the value for the whole population is within plus or minus two standard errors of the estimate for the sample.

At grade four, the percentage of students performing at or above the achievement levels, Basic and Proficient rose from 1990 to 1992. This indicates that at the Basic level (Level 211), more fourth graders should show evidence of beginning to understand mathematical concepts such as number sense and place value and procedures like computation and estimation (from 54 to 61 percent). At the Proficient level (Level 248) students should be able to more consistently apply such mathematical procedures, and should generally be better able to integrate mathematical ideas and procedures in order to solve problems (from 13 to 18 percent). At the Advanced level (Level 280), the percentage of fourth graders did not significantly change from 1990 to 1992. In absolute terms the percentage of students at this level is very small indeed indicating only a small fraction of students should be able to solve a variety of complex and real-world problems in all five NAEP content areas.

The percentage of grade eight students performing at or above the Basic and Proficient achievement levels rose across the two year period, having a pattern of improvement from 1990 to 1992 generally about the same as that for fourth graders. The proportion of eighth graders at or above the Basic level (Level 256) rose from 58 to 63 percent, indicating an increase in the percentage of students who should be able to understand arithmetic operations -- including estimation -- on whole numbers, decimals, fractions, and percents. The percentage of students at or above the Proficient level (Level 294) improved from 20 to 25 percent. These students should be able to apply mathematical concepts and procedures consistently to complex problems in all the NAEP content areas. Like the fourth graders, the percentage of students at or above the Advanced level (Level 331) did not significantly change from 1990 to 1992, and in absolute terms this represents a very small fraction of the eighth grade population.

At grade twelve the percentage of students at or above the Basic level (Level 287) rose from 59 to 64 percent. These students should be able to use reasoning strategies in areas like algebra and geometry to solve problems. The percentage of twelfth grade students at or above the Proficient and Advanced level did not change over the two year period.

Selection of Exemplar Exercises

The purpose of including exemplar items in the reporting process was to demonstrate the range of expected performance for groups of students at the Basic, Proficient, and Advanced levels. The emphasis in identifying and selecting exemplar items and papers was to represent the full range of performance from the lower level to the next higher level with an emphasis on typical performance for the range.

The task for the panel was to select from the set of released items the best possible exemplar items to reflect the levels.[23] Three criteria were used to make those selections. Although a statistical filter was used to select the items for consideration, the primary criterion was a good match between the content of an item and the description of the level it represented. The three criteria were as follows:

- Using the released blocks of items, items whose **expected** p-values did not exceed $p > 0.51$ for any of the levels were deleted.[24] Items were tentatively assigned to the lowest level for which they met the statistical criteria, that is, if an item qualified for the Basic level because the expected p-value ≥ 0.51, it was assigned to that level. If it did not qualify, it was checked for the Proficient level and then the Advanced level.

- Items were then assigned as basic, proficient, or advanced depending on which description they best matched; non-matching items were eliminated. These deletions were based on knowledge of the discussions and intent of the original panels, as well as an understanding of the content frameworks.

- The items retained in the pool also had to have increasing expected p-values from Basic, to Proficient, to Advanced.

Sets of matched and classified items were presented to the validation panels for possible selection as exemplars. The criteria these panels used to make selections were threefold: (1) the perceived quality of the item (e.g., in mathematics, how well it reflected the NCTM Standards); (2) whether, as a whole, the selections were representative of the subscales; and, (3) in the case of items administered to more than one grade, which grade was most appropriate for that item.

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[23]It is typical in NAEP to release about 40% of the test items after each administration. The remaining items are kept secure for use in future cycles. In 1992, five out of 13 blocks (38%) at each grade level were released into the public domain. Only items in one of these 5 grade-level blocks were eligible for selection as exemplars.

[24]The selection of $p \geq 0.51$ as a statistical criterion was a recommendation of the Technical Advisory Committee on Standard Setting (TACSS), an advisory group to ACT, which believed that examinees should have better than a 50-50 chance of being successful on the item for it to be eligible as an exemplar.

The appendix contains nine illustrative exemplar items, one for each of the achievement levels. A fuller set of exemplar items is available from the NAGB to cover the full range of scores within each achievement level.[25]

In summary, achievement levels interpretation provides a new way of looking at the NAEP data by providing guidance on what students should know and be able to do. The process of identifying such levels, in contrast to the NAEP anchoring procedure, is more a judgment process, even though informed by empirical performance data. It is interesting to note that although there were substantial differences between the 1990 and 1992 standard-setting procedures, the results of both, in terms of cut scores and descriptions, are remarkably similar.

To the casual reader, the achievement and proficiency levels look very much the same. In fact, they are quite different. The descriptions that accompany the proficiency levels are derived from the content of the items and the underlying constructs represented in the item pool. In developing the proficiency level descriptions, the expert panels examine all items that anchor in deriving the descriptions. On the other hand, the achievement levels descriptions are not specific to any particular item pool. Rather, they reflect the content domain as represented in the assessment framework. As a matter of fact, the descriptions are developed initially by the panel of judges before examining any items. Throughout the process, these descriptions are then refined and revised as panels become more knowledgeable of the particular NAEP assessment.

The proficiency level descriptions assist in interpreting the anchor points on the scale -- 200, 250, 300, 350. By their very definition they are point-specific. On the contrary, achievement levels assist in describing and interpreting regions on the scale -- Basic, Proficient, and Advanced -- with an emphasis on "typical" performance for each region.

The achievement levels are intended to give some utility and relevance to the NAEP scale. They are meant to assist the nation and jurisdictions participating in the Trial State Assessment in interpreting NAEP scores in terms of a quality standard that has meaning for professional educators, curriculum specialists, prospective employers, policymakers, as well as students and parents. Because the standards apply only to the

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[25]American College Testing, *Description of Mathematics Achievement Level Setting Process and Proposed Achievement Levels Description*. (Washington, DC: National Assessment Governing Board, 1993).

current NAEP frameworks, they do not propose to be national standards, even though they may function as such in the absence of any other national standards.

Alternative Methods for Interpreting the NAEP Scales

As suggested by the discussions of the item mapping and anchor level procedures, even within these two methods many alternatives exist for interpreting the NAEP scale results. For example, in **Beyond the School Doors: The Literacy Needs of Job Seekers Served by the U.S. Department of Labor**, a combination of the item mapping and anchoring procedures was used.[26] The items were mapped onto the scale, and descriptions were developed summarizing performance between various points (i.e., 225 or lower, 226 to 275, 276 to 325, 326 to 375, and 376 or higher). The ranges between points were identified as Level 1 through Level 5, and the percentage of respondents performing at each of the levels was provided. For example, 35 percent of the job training partnership enrollees (JTPA) performed at Level 3 on the document literacy scale, which included tasks designed to measure the knowledge and skills associated with locating and using information contained in job applications, payroll forms, bus schedules, maps, tables, indexes, and so forth. The Level 3 tasks involved integration of more than two features of information in relatively complex displays, with more distracting choices.

6. Building the Interpretation of the Scale into the Instruments

Another alternative is to build the interpretation of the scale into the assessment instruments that comprise it. This has been done by NAEP in reporting the results of the 1984 and 1988 writing assessments.[27] In each of these writing assessments, students responded to a variety of informative, persuasive, and imaginative writing tasks. For example, students were asked to complete brief informative descriptions, reports, and analyses; to write persuasive letters and arguments; and to invent their own stories.

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[26]Irwin S. Kirsch, Ann Jungleblut, and Anne Campbell, *Beyond the School Doors: The Literacy Needs of Job Seekers Served by the U.S. Department of Labor* (Washington, D.C.: U.S. Department of Labor, 1992).

[27]Arthur N. Applebee, Judith A. Langer, Ina V.S. Mullis, Lynn B. Jenkins, *The Writing Report Card, 1984-88* (Princeton, NJ: National Assessment of Educational Progress, Educational Testing Service, 1990).

The papers were evaluated on the basis of students' success in accomplishing the specific purpose of each writing task (as measured by primary trait scoring). The Levels of Task Accomplishment are shown in Figure 1.9.

Figure 1.9

Scoring Rubric for 1984 and 1988 Writing Assessments

	Levels of Task Accomplishment
Score	
4	**Elaborated.** Students providing elaborated responses went beyond the essential, reflecting a higher level of coherence and providing more detail to support the points made.
3	**Adequate.** Students providing adequate responses included the information and ideas necessary to accomplish the underlying task and were considered likely to be effective in achieving the desired purpose.
2	**Minimal.** Students writing at the minimal level recognized some or all of the elements needed to complete the task but did not manage these elements well enough to assure that the purpose of the task would be achieved.
1	**Unsatisfactory.** Students who wrote papers judged as unsatisfactory provided very abbreviated, circular, or disjointed responses that did not even begin to address the writing task.
0	**Not Rated.** A small percentage of the responses were blank, indecipherable, or completely off task, or contained a statement to the effect that the student did not know how to do the task; these responses were not rated.

Based on the primary trait scores for responses to the writing tasks presented in the assessments, the writing data were scaled using the Average Response Method (ARM). The ARM provides an estimate of average writing achievement for each respondent as if he or she had taken all of the writing tasks included, and as if NAEP had computed average achievement -- the average primary trait score times 100 -- across that set of tasks.

Thus, the interpretation of the NAEP writing scale was a direct translation of the scores given the papers. Level 100 denoted unsatisfactory, Level 200 minimal, Level

300 adequate, and Level 400 elaborated, with the definitions of performance at the levels being the same as the definitions used to develop the scoring criteria for the papers.

Acknowledging that most assessments contain a variety of item types, it still might be possible to extend the concept underlying the writing scale analysis to other assessment situations. Particularly, those with a heavy performance component might be conducive to establishing scale interpretation with the development of the tasks themselves, and as part of evaluating student performance on them.

For example, using an item mapping or anchoring procedure for questions evaluated according to levels of success, like the writing tasks, would show for a variety of such items where on the scale students seemed to be achieving partial success, where they seemed to be achieving satisfactory performance levels, and where they seemed to be achieving excellent performance levels. Some aggregate of the data could be used to characterize these levels in an overall sense. Similarly, as part of the development process, individual items could be designated to represent the various levels of understanding within a curriculum area (e.g., partial, full, and extensive), and the results could be aggregated in relation to the scale to represent how many students were at each level of understanding. Based on the aggregations, the percentages of students performing at those levels can be provided.

7. "Benchmarking" the NAEP Scale

It is increasingly common in American industry to strive to reach "Benchmarks" set by the top producers of a product anywhere in the world. The idea is to identify a high quality product that someone is actually making and set that as a standard to strive for. We have adopted that rhetoric in the education reform movement in calling for "World Class Standards." Other methods discussed in this report for interpreting the NAEP scale have dealt with information entirely internal to the NAEP data base. This suggested approach looks outside and asks, where would specific accomplishments be located on the NAEP scale? Benchmarking would attempt to provide guideposts relating

levels on the scale to goals educators could understand and strive for, or to targets actually achieved by others, or to knowledge required to perform a particular activity.[28]

While other approaches communicate what Americans know and can do, or what the National Assessment Governing Board says they should know and be able to do, benchmarks would permit educators and policymakers to set goals that have clear meaning to them, and then see how many students are reaching the goals. They would be concrete and specific, and not abstract. The objective would be to use what is familiar and understood, or what is actually achieved somewhere. Levels such as "Proficient" or particular anchor points on the scale could be conveyed in terms of the real life accomplishments to which they relate.

Actual High Achievement. One easily understood and communicated approach is to select cases of high achievement and to show where that achievement would be on the NAEP scale. The fact that these levels on the scale are actually being achieved gives credence to a goal that is set in terms of those levels. Some of the levels are easy, or relatively easy, to identify. Others would require some work. Some examples are given below in Figures 1.10 and 1.11.

- The average NAEP scale score for the top 10 schools in the NAEP assessment.

  What is NAEP performance at the top? Knowing where the top 10 schools are on the NAEP scale would tell us what is achievable in some places. It is of course, not as simple as it sounds, because our top performing schools are also usually those that have students from the top socioeconomic class....those that exceeded expectations, the "outliers." (discussed in more detail in **What Americans Should Know: Information Needs for Setting Education Goals**.)

- In the highest-ranking State.

  NAEP has identified top-ranking States for some subjects and grades, from the State-by-State assessment. A "top" State could be identified among industrial States, among highly urban States, among rural States, and among poorer States.

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[28]These approaches are explored in *What Americans Should Know: Information Needs for Setting Education Goals*, Paul Barton, (Policy Information Center, Educational Testing Service, 1991).

- Students taking all four years of mathematics, algebra through calculus (or four years in other subjects).
  This can be determined from studies of transcripts of students who take NAEP assessments.

- Students who meet the course-taking standards for college set by the National Commission on Educational Excellence.
  This can also be obtained from transcript studies.

- Proficiencies of students in selected countries.
  This can be done by linking studies, such as international assessments and NAEP assessments. The first such linking study was carried out in 1992. We talk of meeting "world class" standards; this is a way of finding out what they are, in terms of the NAEP scale.

Relating Accomplishments to the Scale. Another way to communicate what particular levels on the scale mean in practical, real life terms is to place specific accomplishments on it. While we may not expect all students to reach some of the high level accomplishments, we will know how many do and can set goals in terms of raising the percentage who are able to. They also can provide a reality check for levels set in other terms, or provide an additional way to convey what a level on the NAEP scale means. One might for example, after defining an "Advanced" level, say that this is a level reached by students who can get a passing score on the forthcoming Pacesetter examination to be introduced by the College Board (if that turns out to be the case). Some examples are provided below in Figures 1.10 and 1.11.

- Passing scores for Advanced Placement courses.
  Where, on a NAEP scale, is the equivalent of a passing score on an Advanced Placement (AP) examination? This could be obtained from a linking study, with NAEP and AP exams given to the same students, or possibly by identifying AP students in the NAEP background questionnaire.

- Passing scores for Pacesetter courses.
  These courses and assessments will be forthcoming from the College Board. The relationship to NAEP scores could be established in the same way as for AP courses.

- Achieving NCTM standards.
  If students achieved the standards set by the National Council of Teachers of Mathematics, where would they score on the NAEP mathematics scale? NCTM standards would be placed on the NAEP scale by a panel of experts who would look at each NAEP question and judge whether a student who achieved the standards would get it correct.

- Meeting the standards of the New Standards project.
  As assessments are constructed for the New Standards Project, linking studies could place them on the NAEP scale.

- Meeting the expectations of employers...employer benchmarks.
  The reading and mathematics level needed to enter a few specific occupations would be identified as markers for preparation in school for the employment world. These could be established by conducting a job analysis, establishing panels of employers who hire for those occupations, or giving NAEP to a sample of people working in those occupations.

- Meeting the expectations of teachers...teacher benchmarks.
  A sample of teachers of students assessed by NAEP would be asked to judge each item. They would be asked to determine which questions they would expect their students to answer correctly. These teacher expectations would be placed on the NAEP scale. We would know the level of expectations, how they change over time, and the gap between expectations and performance.

In summary, as shown in Figures 1.10 and 1.11, the benchmarking approach to interpreting the NAEP scale is quite different from the other methods discussed. It is

aimed at being concrete, rather than abstract, grounding the scale in real life performance comparisons outside the NAEP assessment, where specific accomplishments, or expectations of teachers and others define the standards. This method might work especially well in conjunction with some of the other methods described, for example, together with a detailed item mapping technique to provide diagnostic information about which understandings must be improved to reach the targets specified.

Figure 1.10 – Hypothetical Examples of High Achievement Benchmarks (National Assessment of Educational Progress)

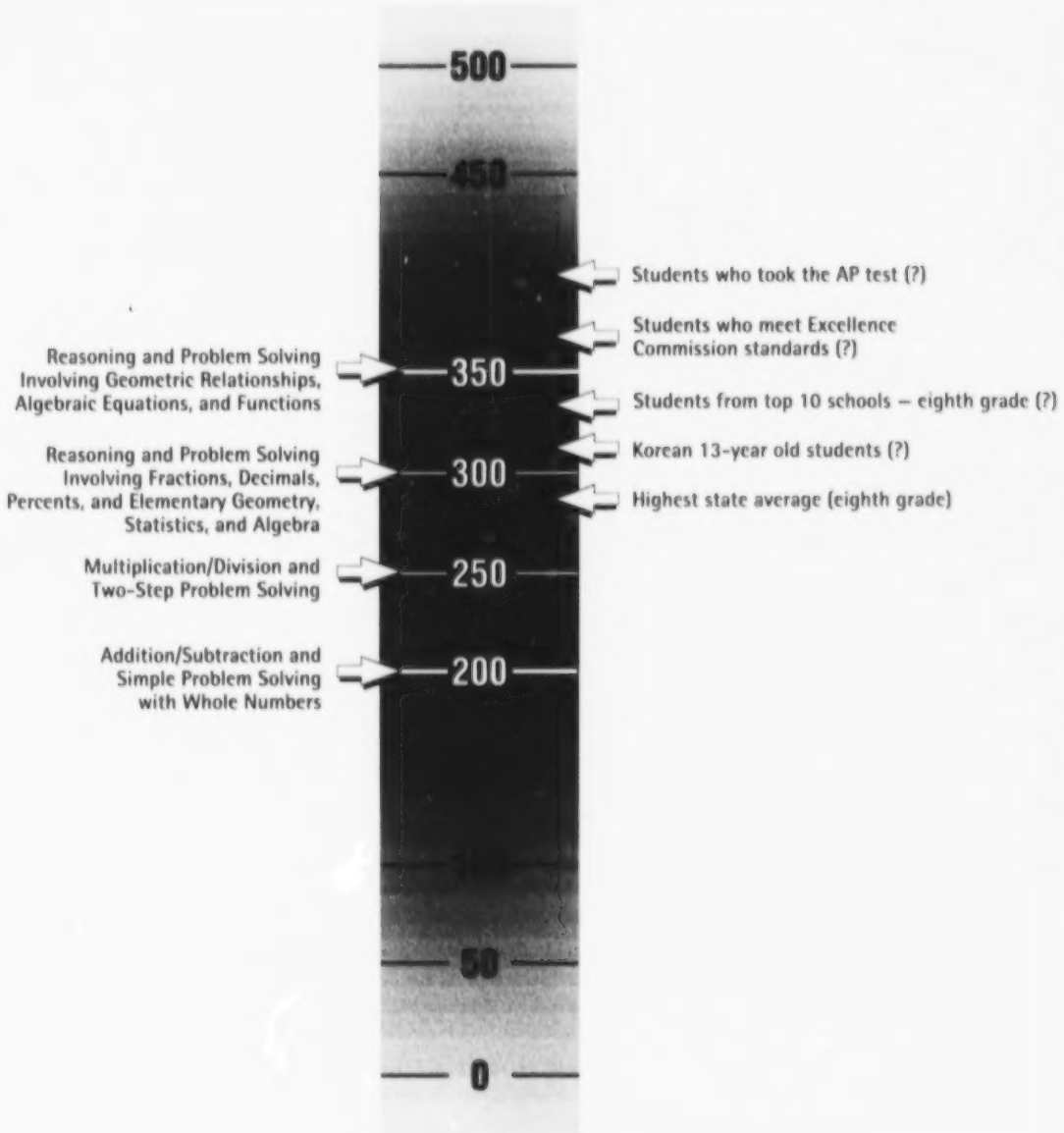
500
450
350
300
250
200
50
0
Students who took the AP test (?)
Students who meet Excellence Commission standards (?)
Students from top 10 schools – eighth grade (?)
Korean 13-year old students (?)
Highest state average (eighth grade)
Reasoning and Problem Solving Involving Geometric Relationships, Algebraic Equations, and Functions
Reasoning and Problem Solving Involving Fractions, Decimals, Percents, and Elementary Geometry, Statistics, and Algebra
Multiplication/Division and Two-Step Problem Solving
Addition/Subtraction and Simple Problem Solving with Whole Numbers

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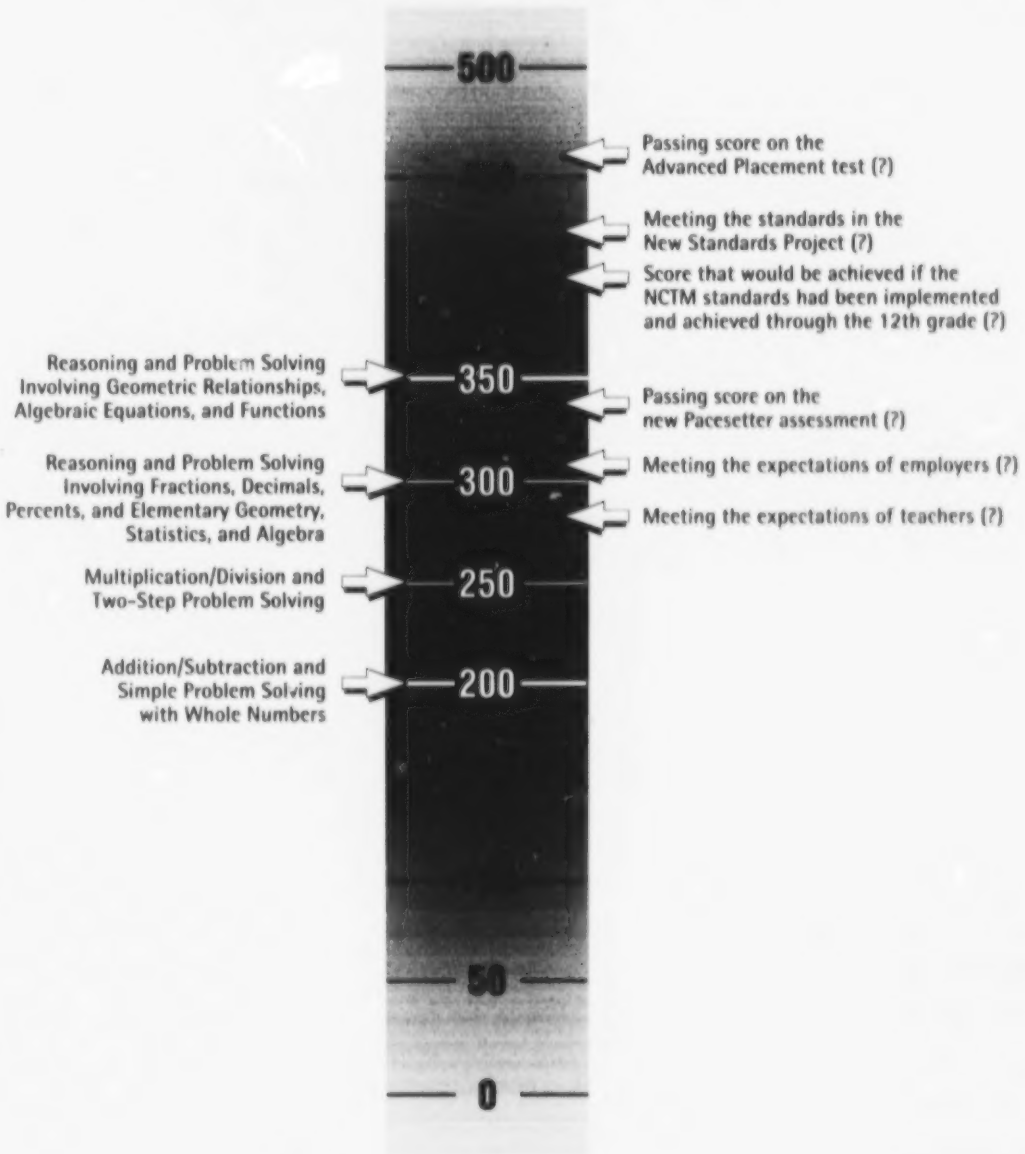
Figure 1.11 – Hypothetical Examples of Accomplishment Benchmarks (National Assessment of Educational Progress)


500
Passing score on the Advanced Placement test (?)
Meeting the standards in the New Standards Project (?)
Score that would be achieved if the NCTM standards had been implemented and achieved through the 12th grade (?)
Reasoning and Problem Solving Involving Geometric Relationships, Algebraic Equations, and Functions
350
Passing score on the new Pacesetter assessment (?)
Reasoning and Problem Solving Involving Fractions, Decimals, Percents, and Elementary Geometry, Statistics, and Algebra
300
Meeting the expectations of employers (?)
Meeting the expectations of teachers (?)
Multiplication/Division and Two-Step Problem Solving
250
Addition/Subtraction and Simple Problem Solving with Whole Numbers
200
50
0

Summary

This chapter has described some concrete examples of how NAEP data can be used to present information about the educational health of our nation. For example, the percentages of students responding correctly to particular items can be powerful and interesting information in and of themselves. Some citizens might consider it a matter of concern that only 21 percent of the fourth graders could calculate the amount of change that should be received from $10.00 if they bought two calculators for $3.29 each.

On the other hand, summary indices that synthesize results across items, such as the NAEP scale with its various opportunities for interpretation, also provide valuable information. Performance on the NAEP scale, which ranges from 0 to 500, can be interpreted is through an item mapping technique. The percentages of students performing at or above levels on the scale are presented together with items along the scale. That is, items are shown on the scale where most students performing at that level would be likely to answer the item correctly. This method provides a portrait of achievement through example, and the percentages performing at or above the various levels can be used for monitoring progress.

In contrast to portraying performance along the scale, as is done in item mapping, scale anchoring provides a description of performance at regular intervals on the scale, called the anchor levels. Each level is described according to the types of questions that are likely to be answered by students at that level, but less likely by students below. This method also uses the percentages of students performing at or above the various levels on the scale for monitoring progress. A strength of this method is that the information provided by the anchoring process to describe performance at the anchor levels can be presented in a variety of forms, from very concise to extensively detailed.

The NAEP achievement levels represent an alternative to the scale anchoring process. They result from an effort to prescribe what students should know and be able to do, as opposed to the scale anchoring process which is descriptive.

When the levels of performance are built into the scoring procedures for constructed-response tasks, as with the writing assessment, then the levels of performance can be an integral part of the scale. Or, in the future, the NAEP scale could be interpreted through other real-life educational experiences that indicate high educational achievement (e.g., students who have taken calculus in the United States or advanced curricula in other

industrial nations) or particular accomplishments (e.g., the passing score on an AP test or the expectations of employers for an entry level job).

A variety of ways of giving meaning to the NAEP scale will accommodate the variety of ways different people think about education, their needs and expectations of the system, and the ways they go about setting targets and goals to raise achievement.

CHAPTER 2
ISSUES IN INTERPRETING NAEP SCALES

Background

Since its initial administration in 1969, NAEP has been reporting information on the academic progress of nationally representative samples of American school-age students and young adults. The information that NAEP provided throughout the 1970s appeared to meet many of the information needs policymakers had at the time, without being intrusive into State and local control of education. Results were reported by age rather than grade, and performance data were reported at the exercise (test item) level. In short, through the 1970s NAEP met the demands that were placed on it while not being required to play a major role in driving public educational policy. As Messick, Beaton, and Lord have observed, "The original design of the National Assessment of Educational Progress (NAEP) was brilliantly responsive to the political constraints of the time."[29]

Many factors in the fabric of educational policy and practice converged in the 1980s, however, that virtually demanded NAEP be redesigned to meet increasing needs for an enhanced national achievement indicator.[30] Among those factors were the accelerating accountability movement among the States as well as, more recently, an increased executive and legislative interest in educational policy factors, taken singly or together, increased the technical and reporting demands placed on NAEP and significantly increased the stakes associated with NAEP assessment.[31]

Beginning in 1983, and partially in response to those changing environmental factors, NAEP underwent a major change in its design. This change in design increased its capability to provide information that is relevant for educational policymakers and the

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[29]S. Messick, A. Beaton, F. Lord. *National Assessment of Educational Progress Reconsidered: A New design for a New Era*. NAEP Report No. 83-1. (Princeton Educational Testing Service. 1983), 1.

[30]Ibid.

[31]National Academy of Education, *Assessing Student Achievement in the States*. The First Report of the National Academy of Education Panel on the Evaluation of the NAEP Trial State Assessment: 1990 Trial State Assessment, 1992.

public at large. One of the most profound design changes was the introduction of an Item Response Theory (IRT) - based scale that ranged from 0 to 500. The development and implementation of scale scores with reading in 1984 and mathematics in 1986 opened many new possibilities for reporting and interpreting student performance that were not available with item-level only reporting. Some of the benefits included: the flexibility of using different items across time and still maintaining the same scale; the capacity to correlate achievement data with a plethora of student, teacher, and school background information; the creation of a summary index across items that simplified the results for policymakers, the press, and the public; and the provision of a scale that, potentially, could yield criterion-referenced, as well as norm-referenced interpretations.

1. Norm-referenced and Criterion-referenced Interpretations

The scales on which educational and psychological test scores are reported have been a major source of confusion for educators, policymakers, and the public throughout the history of testing. IQ scores, SAT and ACT scores, grade-equivalent scores, and percentile scores are just a few of the scores that are confusing to many. Even the simplest of distinctions, percents and percentiles, are regularly confused by educators, policymakers, and the public.

The average IQ score is 100 and most IQ scores fall between 70 and 130. Why? Because we arbitrarily chose to report scores that way. SAT scores, on the other hand, are used in college admissions and have an average score of around 500. Most scores fall between 400 and 600 and all scores fall between 200 and 800. ACT scores, which are also used in college admissions, have their own metric, i.e., scale, for reporting scores. An average score is 21 and most scores fall between 10 and 30. Here we have two tests used for the same purpose being reported on very different scales. NAEP mathematics scores in 1990, on the other hand, were reported on a 500-point scale with the average score for a nationally representative sample of 4th, 8th, and 12th graders being 250. Most scores fell between 150 and 350. The message should be clear. The scales on which most test scores are reported are quite arbitrary and are chosen by test developers to distinguish between tests and to enhance the interpretability of test scores.

Almost all testing and assessment programs attempt to provide methods of interpreting their scores. Such interpretations give meaning to the scores and make the results of the testing understandable to the general public. The basic problem in the case of NAEP at the current time is how to best give meaning to the NAEP scale scores. The two major approaches to providing meaning to test scores are called norm-referenced and criterion-referenced interpretations.

A norm-referenced interpretation is obtained by comparing examinee scores to a well-defined comparison group (usually a nationally representative sample). The norm-referenced score tells how well the student did in comparison to the norm group. Some examples include percentiles, grade equivalents, stanines, quartilies, and standard deviation units.

A criterion-referenced interpretation is obtained from test scores by comparing examinee scores to a well-defined content domain. As a general rule the content domain is defined via an explicit set of test objectives, and item and test specifications, around which the test is built. Criterion-referenced interpretations indicate what a student knows and can do. Since they are grounded in specific content objectives, they are typically more instructionally relevant. The difference is similar to contrasting a swimmer's place in a race (a norm-referenced comparison) to his or her time in finishing the race (a criterion-referenced comparison). Both interpretations are important, but they may yield different impressions of the same performance. A swimmer may finish first place on a local swim team (i.e., he or she is excellent relative to a local norm), but his or her time may never qualify for the Olympics (relative to high absolute standards).

Many policymakers and educators, as well as the public, seem to want scales for test score reporting that have as much criterion-referenced meaning as thermometer scales for measuring temperature or yardsticks for measuring distance. People over the years have learned to attach meaning to points (temperatures) on the thermometer scales. They know what happens at 32°, and they know how they feel at 68° and 98.6°. They also know the effects at 212°. (This is called benchmarking in Chapter 1.) Unfortunately, in educational testing, student achievement is being measured and for these measurements we must create new reporting scales that will be arbitrary (like the temperature scale) but will not have the clarity of meaning associated with scales to measure temperature, distance, weight, and many other physical measurements. The clarity will need to come through

experience with the scales. But, hardly any educational test score reporting scales have been around long enough or have remained stable enough over time for persons to become as familiar with them as they are with thermometers, rulers, and weight scales.

The National Center for Educational Statistics is aware of problems that have plagued many score reporting systems. In fact, some of the same criticisms of many score reporting systems have been leveled at NAEP. NCES has sought to enhance the utility of NAEP score reporting by using scales that will have a clear meaning and be useful for describing student performance and measuring trends using cross-sectional designs. Many steps have been taken to achieve this goal, though the effort has not been without some criticism.[32] In this chapter, the validity of different ways of interpreting NAEP scales will be considered. Of special interest is the new way of reporting NAEP data - the achievement levels and the evidence that should be compiled to support the intended interpretations of these levels. Unless the scales, the proposed framework for interpreting selected scores, and achievement levels can stand up to technical criticisms, the scales will have limited value for influencing educational policy and practice.

2. Validity

Thirty-two degrees on the Fahrenheit scale is known as the point at which water freezes. The accuracy or validity of this interpretation of 32 degrees was established long ago. But it would be easy to conduct a study or experiment today to validate the interpretation of 32 degrees as the freezing point of water. In much the same way, through the compilation of evidence, the validity of the various interpretations of the anchor and achievement levels needs to be established as well. These points were established for a good reason, i.e., to enhance the meaning and usefulness of the NAEP reporting scale, but evidence must be compiled to show that these points can serve their intended purposes. Evidence must be compiled that lends credibility or believability to the intended interpretations of these points.

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[32]R.A. Forsyth, "Do NAEP scales yield criterion-referenced interpretations," *Educational Measurement: Issues and Practice*, 1991, 10, pp 3-9, 16.

Validity is a characteristic of the inference made from test scores, it is not a characteristic of any specific test instrument, such as the NAEP tests, that produces these scores. Therefore, it is not correct to refer to NAEP, or any test, as a valid or invalid test instrument. Rather, "...[validity] refers to the appropriateness, meaningfulness, and usefulness of the specific inferences made from *test scores* [italics added]".[33] It is from test scores that inferences are made; it is the interpretations of the test scores that must be validated for the various ways in which they are used. The test developer has the responsibility for providing evidence of the validity of the score interpretations that are likely to be made from the test results.

3. Validity Issues With Scale Anchoring

In Chapter 1 we have described the rationales for, and the development of, the NAEP anchor points. The purpose of the anchor points is to give meaning to the scales that are used to report the performance of groups of students. This is a very important point to keep in mind; the anchor level descriptors describe outcomes that students can do at specific points on the NAEP scale. The descriptors are intended to give meaning to selected points on the NAEP scale and to reference student performance to understandable behaviors that have been specified in the NAEP assessment frameworks. Student performance relative to the anchor levels should not be used as a predictor of student performance on other measures or to support inferences that go beyond describing student performance relative to the NAEP content.

The intended meaning of the anchor levels for the 1992 mathematics assessment is fully described in Chapter 1 of this volume. As an example, the anchor level represented by a scale score of 250 generally represents student understanding of addition, substraction, multiplication, and division with whole numbers. It also represents the capacity to perform two-step problem solving exercises.

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[33] *American Educational Research Association, American Psychological Association, National Council for Measurement in Education, Standards for Educational and Psychological Testing*, (Washington, DC: 1985).

Interpreting actual student behaviors from the anchor level descriptions must be done cautiously. While the description of the anchor level 250 suggests that students have a general understanding of arithmetic operations, it does not follow that students are able to perform all possible exercises that involve arithmetic operations. Furthermore, there may be very few assessment exercises that relate to specific knowledge and skills implied in the anchor point descriptions, such as division. For the anchor levels, there may be as few as one exercise that pertains to some of the specific knowledge and skills in the level descriptions.

For example, many students at level 250 may be able to use basic arithmetic operations to solve simple mathematical exercises, but few of them may be able to use those operations as successfully if the numbers are large or the context of the application is more complex. Such advanced behavior probably would be suggestive of performance at a higher anchor level.

Consequently, there is always the danger of over-interpreting student performance at the anchor points. That is, one might assume that all students at a level 250 understand and apply basic mathematical operations in all contexts. Clearly, this is not the case, and to sustain such a position would be an invalid interpretation of level 250 performance.

Anchor level descriptions, along with their illustrative items, provide a general indication of performance at each anchor point. Taken as a whole, the combination of descriptions and illustrative items give the public and education professionals that capacity to reference points on the NAEP scale to what students generally know and can do.

Several forms of evidence for the validity of the processes for relating student behaviors, such as those described just above, to a specific anchor point (250, for example) have been gathered by Educational Testing Service. First, the test items that serve as the basis for the description and interpretation of each anchor point were carefully selected to distinguish between scores at adjacent anchor levels. Clear distinctions among anchor levels must be possible or the interpretations about the proportion of the sample at or above each point cannot validly be made. Second, a national committee of mathematics experts was divided into two groups. Each group independently generated anchor level descriptions. The descriptions generated by each group were very similar, suggesting that

the descriptions did indeed reflect student behaviors at each anchor point, given the selection rules discussed in Chapter 1. Third, there is statistical evidence to support the fit of the psychometric model used in data analysis, hence the locations of the items on the NAEP scale - central to the anchor and achievement level descriptions - are without serious dispute. Thus, there is evidence for the internal validity of the processes use to develop the anchor level descriptions and for the inferences that are made about what students know and can do at each anchor level. However, prior to discussing how the proportions of students at or above each anchor point are interpreted as an indicator of educational progress, one important characteristic of the anchor level descriptions will be reviewed.

The anchor level descriptions were derived using the selection rules listed in Chapter 1. Recall that the method used for generating the anchor level descriptions included a priori selection of points on the NAEP scale. Items whose difficulty values corresponded to each of these points, and that also met the statistical criteria, were then identified. Among the statistical criteria was the requirement that each item have a p-value of at least .65. Based on the items identified at each anchor point, two randomly-equivalent groups of mathematics experts then made informed inferences about likely student behaviors for each anchor point.

While interpretations of student performance in the NAEP sample can be made based on the internal, process validity evidence, the decision to use the 65% criterion for describing the anchor levels has had an important influence on the standard of performance that is actually interpreted at any anchor level. Early in the anchoring process an 80% rule was used for selecting items from which level descriptions were developed. Later the 65% criterion was adopted. The choice of the statistical criteria for selecting items to be used to develop anchor level descriptions is important, because different criteria are likely to lead to different descriptions. Given that the underlying distribution of scores is independent of the descriptions, inferences about the status of the student sample's performance are likely to be different for different criteria.

Selecting items using a 65% criterion, for example, would result in selecting a more difficult set of items upon which to base anchor level descriptions than an 80% criterion. Descriptions that are referenced to a more difficult (the 65% criterion) set of items will reference more challenging content than descriptions that are referenced at less challenging levels (the 80% criterion).

From an interpretive perspective, more challenging descriptors will give a different picture about national achievement than less challenging descriptors. As noted above, since the proportions of examinees at each level remain the same, more challenging descriptions could lead to a more sanguine interpretation of the status of achievement nationally than less challenging descriptions.

The selection of the statistical criteria for description development was an arbitrary one. Arbitrary decisions about the statistical criteria are not necessarily inappropriate. As long as the statistical criteria remain the same over an extended period of time, trend data can be meaningfully interpreted. Experience with the performance data and descriptions will enhance the interpretability of the data and allow policymakers to become comfortable with the use of data in crafting educational policy.

The interpretation of the proportions of students at or above each anchor level is important descriptive information about the performance of American students. These proportions are presented in Table 1.1 of Chapter 1 in this volume. It is appropriate to interpret these data as reporting the proportions of all students in the United States who would have scored at or above each anchor level had all students been administered the NAEP tests, given the sampling methodology that was used to collect that data. We can be very certain, within the limits of the measurement error, that 15 percent of the eighth grade students in 1990 scored at or above 300 and that 20 percent of eighth grade students scored at or above that same level in 1992.

In addition to interpreting the performance of proportions of students at or above each anchor level, NAEP data also allow the interpretation of proportions of students correctly responding to sample test items (p-values). The sample items are illustrative of each of the anchor levels, and along with the anchor level descriptors, are intended to add meaning to the 500 point NAEP scale.

While p-values are very straightforward to interpret (the proportion of examinees correctly answering an item or exercise), because there can be many p-values associated with any sample item, care must be taken to correctly interpret the group of students for which the p-values have been calculated. Further, extreme care must be taken when p-values are interpreted within the context of anchor levels. A specific example follows from the sample item presented in the Appendix that illustrates level 300 performance. Consider the following table:

Table 2.1 Percentage Correct (P-Values) and Proportions of Grade 8 and Grade 12 Students at or above Anchor Levels for an Exemplar Item

	Anchor Level			
Grade 8: 40% Correct Overall (p-value)	200	250	300	350
% Correct for Anchor Levels (conditional p-value)	16	22	62	90
Proportion of Grade 8 Students at or Above Anchor Levels	97	68	20	1
Grade 12: 69% Correct Overall (p-value)				
% Correct for Anchor Levels (conditional p-value)	-	33	72	97
Proportion of Grade 12 Students at or Above Anchor Levels	100	91	50	6

There are nine p-values, associated with this item in this display. While this item was administered at both grades eight and twelve, most items in the NAEP assessment are administered at one grade. Very few are administered at all three grades. There is one overall p-value and four conditional p-values at grade eight, and one overall p-value and three conditional p-values at grade twelve.

Forty percent of all eighth grade students correctly answered this item, and sixty-nine percent of all twelfth grade students correctly answered this item. The p-values for each anchor level are called "conditional" because they are the proportion of students correctly answering the item for students at the anchor level (i.e., students whose scale score was between 12.5 scale score points above or below the anchor level). It is important to understand that the conditional p-values are representative of only a fraction of the total population - those students scoring near the anchor level.

So far this discussion has presented interpretations of overall p-values by grade and conditional p-values by anchor level for each grade. There is, however, further possibility for confusion in interpreting student performance when the item p-values for students at each level are confused with proportions of students scoring at or above each anchor level.

A common error in interpreting anchor level performance is confusing the proportion of students correctly answering an item with the proportion of examinees scoring at each anchor level. This confusion has been described in detail by Linn and Dunbar,[34] and in Chapter 1 of this volume. Using the information from the level 300 item above, we know that 40 percent of all the eighth grade students answered the item correctly. Further, 20 percent of the students scored at or above anchor level 300. Upon a cursory reading of the results, one might improperly conclude that only 20 percent of the students answered the item correctly because the item anchored at a level 300.

In this example, the misinterpretation that 20 percent answered the item correctly, when in fact 40 percent answered it correctly, would be understating the performance of the sample. Understating the performance could then give rise to greater alarm about more general and invalid interpretations about student performance.

There are other cautions as well that need to be heeded when interpreting sample items that illustrate performance at the anchor levels. A sample item illustrating a specific anchor level does not address performance of students at higher or lower anchor levels. Using the item above as an example, it is incorrect to assume that students achieving at anchor levels less than 300 would necessarily incorrectly answer the item. Examinees scoring just below a scale score of 300 have nearly as much chance of correctly answering the level 300 item as students scoring at that level.

Conversely, it would be incorrect to assume that all students above a scale score of 300 would answer the item correctly. Some students scoring above 300 may incorrectly answer the item. For example, the conditional p-value for all students scoring at 350 in grade eight is 90 percent, meaning that 10 percent of the students at level 350 did not answer the item correctly.

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[34]Robert L. Linn and Steven B. Dunbar, "Issues in the Design and Reporting of the National Assessment of Educational Progress," *Journal of Educational Measurement*, 1992, vol. 29, pp. 177-194.

Valid interpretations beyond describing the actual proportions at or above each anchor level, or performance by each item, become much more problematic. Going beyond reporting the actual proportions of sample members at or above the NAEP anchor levels has been criticized on validity grounds. Forsyth has made this point very clearly.[35] He cites, among other examples, interpretations made regarding the performance of students based on the 1986 Science Report Card.[36] As Forsyth points out, the authors of that report interpreted the results of student performance on the science assessment as meaning that students were not prepared to participate in civic affairs. This generalization by the authors was based on their interpretation of low scores on thinking skills and science knowledge, outcomes that are presumably related to informed civic participation.

The problem with this interpretation, as Forsyth correctly indicated, is that while the generalization may have been correct, there was no validity evidence for such an interpretation. Such evidence is required by the **Standards for Educational and Psychological Testing**.

Specifically, Standard 1.1 indicates:

> Evidence of validity should be presented for the major types of inferences for which the use of a test is recommended. A rationale should be provided to support the particular mix of evidence presented for the intended uses. (p. 13).

Standard 1.2 requires that:

> If validity for some common interpretations has not been investigated, that fact should be made clear, and potential users should be cautioned about making such interpretations. Statements about validity should refer to the validity of particular interpretations... (p. 13).

Extending interpretations beyond the actual data is an important issue when evaluating the 1992 mathematics results. There are important educational and policymaking reasons in wanting to extend interpretations from the NAEP data base. Because the NAEP data base is so comprehensive and important, it is only natural to want

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[35]Robert A. Forsyth, "Do NAEP Scales yield criterion-referenced interpretations?" *Educational Measurement : Issues and Practice*, 1991, 10, pp. 3-9, 16.

[36]Ina V. Mullis and Lynn B. Jenkins, *The Science Report Card: Elements at Risk and Recovery*, (Washington, DC.: U.S. Department of Education, 1988).

to find as much meaning in the results as possible. However, the relationship between student performance as reflected by the anchor levels and other important issues, such as, readiness for advanced mathematics study, the adequacy of the mathematics curricula among the nation's schools, and understanding whether current performance is sufficient to compete in today's international marketplace, has simply not been established.

This is not meant to suggest that such relationships cannot or should not be established, but rather they are not currently part of the validity data that has been collected for NAEP. To extend interpretations beyond performance on the NAEP scale itself, without validity evidence for these interpretations, would be inappropriate.

4. Validity Issues with Achievement Levels

Reporting NAEP results relative to what students should know is a qualitative change from reporting what students do know. Such a change recognizes the role NAEP assessments may have in the future relative to the continuing trend toward the identification and assessment of national curriculum standards. Various proposals have been suggested, such as those found in AMERICA 2000,[37] the National Educational Goals Panel Report,[38] and the report of the National Council on Education Standards and Testing, [39] that suggest some policymakers would like to see NAEP assume a more direct role in the assessment of national educational standards.

There are other examples of extended uses of NAEP scores that would not have been possible in the past, uses that are far beyond NAEP's original purpose of monitoring the achievement of groups of students at the national and regional levels. Some of the recent applications of NAEP data include:

1. the Trial State Assessments conducted in 1990 and 1992

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[37]U.S. Department of Education , *AMERICA 2000: An Education Strategy*, 1991.

[38]National Educational Goals Panel Report (NEGP), *The National Educational Goals Panel Report: Building a Nation of Learners*, (Washington, DC: NEGP, 1991).

[39]The National Council on Education Standards ad Testing, *Raising Standards for American Education*, (Washington, DC.: U.S. Department of Education, 1992).

2. the recasting of the achievement levels by the National Educational Goals Panel to define competent student performance[40]
3. the use of NAEP items for the 1988 and 1991 International Assessment of Educational Progress, (IAEP).[41]

Another potential use of NAEP data and scales is being considered by NAGB. Currently NAGB is considering establishing a policy for linking other assessments, such as state, local, and commercial tests, to the NAEP scale. In fact, California,[42] Maryland, and Kentucky have already shown interest in linking their state assessment results to the NAEP scale.

These and other demands on NAEP and the NAEP scale represent a trend in which the stakes for NAEP testing have increased. Raising the stakes for NAEP puts an additional burden on all components of the NAEP assessment, and particularly on those who wish to make valid interpretations of NAEP scores. There is growing evidence that misunderstandings of NAEP scales and scores result in interpretations that are not necessarily supported by the data.[43 44 45 46] Given the increasingly high stakes uses of NAEP results, it is critical that the validity and invalidity of various interpretations are known. It is only in this way that public policy can be illuminated based on valid inferences from the test results.

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[40]NEGP, 1991.

[41]Two reports relate to the use of NAEP scales for IAEP Assessments. They are:

Archie E. Lapointe, Nancy A. Mead, and Gary W. Phillips, *A World of Difference: An International Assessment of Mathematics and Science* (Report No: 19-CAEP-01, Princeton: Educational Testing Service, 1989).

IAEP Technical Report: Volume Two,(Princeton: Educational Testing Service, 1992).

[42]Stephen G. Schilling and R. Darrell Bock, *Relating CAP Grade Twelve Reading and Mathematics Scale Scores to NAEP Reading and Mathematics Scores*, 1989.

[43]Robert A. Forsyth, 1991.

[44]R. Glaser and R. Linn, *Assessing Student Achievement in the States: The First Report of the National Academy of Education Panel on the Evaluation of the NAEP Trial State Assessment*, (Stanford, CA: National Academy of Education, 1992).

[45]Richard M. Jaeger, "General issues in reporting of the NAEP Trial State Assessment results," in Glaser, R. and Linn, R., *Assessing Student Achievement in the States*, (Stanford, CA: National Academy of Education, 1992).

[46]Robert L. Linn and Steven B. Dunbar "Issues in the design and reporting of the National Assessment of Educational Progress," *Journal of Educational Measurement*, 1992, 29, 177-194.

In the future it is expected that achievement levels will replace anchor levels as the primary way of reporting NAEP results. With the increased visibility of NAEP, it will become more important in the future to address issues of validity. A recent United States General Accounting Office (GAO) correspondence[47] and a planned GAO report have highlighted the need to attend to the validity of inferences from the achievement levels. Unfortunately, no single study or piece of evidence is likely to be sufficient to either validate or invalidate the intended interpretations. It is usually a matter of compiling a substantial amount of information and then considering it in a comprehensive way. This concept of assessing validity through compiling evidence is captured nicely by the **Standards for Educational and Psychological Testing**:

> Validity is the most important consideration in test evaluation. The concept refers to the appropriateness, meaningfulness, and usefulness of specific inferences made from test scores. Test validation is the process of accumulating evidence to support such inferences. A variety of inferences may be made from scores produced by a given test, and there are many ways of accumulating evidence to support any particular inference. Validity, however, is a unitary concept. Although evidence may be accumulated in many ways, validity always refers to the degree to which that evidence supports the inferences that are made from the scores. The inferences regarding specific uses of a test are validated, not the test itself.

In line with this view of gathering validity evidence from a variety of sources, and anticipating the importance of the achievement levels in the future, the National Academy of Education (NAE) has agreed to conduct a series of 10 validity studies based on the achievement levels developed by the NAGB in 1992. The results of the 10 studies will be available in the fall of 1993 and are part of a larger set of 22 studies being conducted as part of the Congressionally mandated evaluation of the Trial State Assessment.

The National Academy of Education Panel, in their evaluation of the achievement level setting process, introduced a useful distinction between internal and external validity evidence. Internal evidence comes from the processes themselves, the methods and procedures used by and with judges as recommendations about standards and

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[47]National Assessment Technical Quality. GAO Correspondence to Congressman Ford and Kildee, March 11, 1992. GAO/PEMD-99-22R.

level descriptions. If, for example, processes and methods were changed, or a different panel of judges were used, to what extent would the results be altered?

External evidence has to do with data external to the process itself that can be used to support or refute the desired interpretations of the anchor and achievement levels. In large and unusually complex projects that have increasingly high stakes associated with them, substantial amounts of internal and external data are needed to support the strong interpretations associated with the anchor and achievement levels. Both internal and external sources of validity data will be discussed in the following sections.

The NAE divided their studies into four external validity studies and six internal validity studies. The external validity studies involve comparing the results obtained by NAEP to external information. The four studies will compare NAEP results to:

1) teacher judgments who use the operational definitions of basic, proficient and advanced to categorize students
2) international data equated to NAEP
3) levels of performance of 12th graders to college admissions tests
4) the content judgments of a cross-validation sample of subject experts.

The six internal validity studies are analyses of the process NAGB use to set achievement levels. The studies include an analysis of:

1) the differential effects in setting the achievement levels caused by the differing item formats (e.g., multiple-choice versus constructed responses)
2) the sources of error in setting the achievement levels
3) the variation in achievement levels across the different content areas
4) the setting of three achievement levels from each item rather than the usual one standard in the Angoff procedures
5) judgments from teachers and others on the achievement levels
6) the observations of the entire achievement level-setting process.

Collectively, this series of studies should provide sufficient evidence to make informed judgments about the validity of the achievement levels.

In addition to the recommended internal and external validity studies that are either completed or underway, more global concerns about the capacity of the National Assessment, as currently conceived, to maintain its status as a valid achievement indicator must be raised. A specific example follows.

The historical approach to establishing achievement levels for mathematics and reading has been a model where content is first specified through frameworks, item specifications and assessment items and tasks are written consistent with the frameworks, the assessments are administered, and then achievement levels are developed. One of the problems this approach creates is that there may be a lack of consistency between the achievement level standards and what the assessment actually measures. (As an example, the eighth grade mathematics basic achievement level description indicates that students should be able to solve problems using computers. Computer usage is not a part of the NAEP mathematics assessment.) The question arises, what are the validity issues for assessing progress toward standards when the assessment instrument may not reflect the standards?

One model for the development of assessment instruments and achievement levels that would eliminate this validity problem would be to move to a developmental sequence where the achievement level standards are established first, and then the frameworks, items and tasks, and assessment instruments are developed and implemented. This model would ensure the consistency between the assessment instrument and the achievement level standards, and enhance the validity of both.

The larger validity issue, however, is whether the NAEP assessment can measure prespecified world-class standards without undergoing some basic design transformations. If the model of specifying the achievement level standards first in the development process were implemented, it is conceivable that the standards would place a very high premium on content that was challenging for most American school children. Such high standards would require the development of an assessment instrument that measures well at the high end of the achievement distribution. The NAEP assessment, currently designed to measure what students know and can do across all parts of the achievement distribution, would need to focus much more at the upper end of the

distribution due to the more challenging content (standards). For a given amount of testing time, focusing the assessment at the upper end will, by necessity, result in an assessment instrument that measures students less well at the mid- to lower-ranges of the achievement distribution.

Interpretations of the Point 300 on the NAEP Mathematics Scale

As has been discussed in this chapter, interpretations of test scores must be validated by the compiling of evidence. Currently we have two major ways of interpreting the NAEP scales -- by anchor levels and achievement levels. The interpretations of anchor levels have been designed to indicate what students can do in mathematics at a certain point on the scale. In contrast, descriptions of the achievement levels are designed to indicate what students should be able to do in mathematics at a certain range on the scale. We will use the 300 point on the NAEP scale to illustrate this difference more clearly.

Using the anchor level interpretation of 300, the overall description of the level is that students can use reasoning and problem-solving involving fractions, decimals, percents, and elementary concepts in geometry, statistics, and algebra. More specifically, students at this level can use various strategies and explain their reasoning in a variety of problem-solving situations. They are able to solve problems involving not only whole numbers but also decimals and fractions. They can represent and find equivalent fractions, and use these concepts in solving routine problems. They can find a percent of a number and use this skill in simple problems. Multiplication and division of whole numbers have developed to the extent that students can use all four operations in multistep problems.

Students can read and use instruments in more complex situations. They can find areas of rectangles, recognize relationships among common units of measure, and solve routine problems involving similar triangles and scale drawings. They have knowledge of definitions and properties of simple geometric figures in the plane. Their spatial sense includes the ability to visualize a cube in either three-dimensional space or its flattened form in a plane.

Students can calculate averages, select and interpret data from a variety of graphs, list the possible arrangements in a sample space, find the probability of a simple event, and have a beginning understanding of sample bias. They can use knowledge of relative frequencies in simple simulation situations. Students show the ability to evaluate

simple expressions and solve linear equations. Students can graph points on coordinate axes, locate the missing coordinates for a corner of a square, and identify which ordered pairs satisfy a given linear equation.

Using the same point 300 with achievement levels, there are three descriptions of what students should be able to do at this point, depending on whether they are in fourth, eighth or twelfth grade.

Fourth grade students at 300 are within the Advanced range and should apply integrated procedural knowledge and conceptual understanding to problem solving in the five content areas. Fourth graders performing at the advanced level should be able to solve complex and nonroutine real-world problems in all NAEP content areas. They should display mastery in the use of four-function calculators, rulers, and geometric shapes. These students are expected to draw logical conclusions and justify answers and solution processes by explaining why, as well as how, they were achieved. They should go beyond the obvious in their interpretations and be able to communicate their thoughts clearly and concisely.

Eighth grade students at 300 are within the Proficient range and should apply mathematical concepts and procedures consistently to complex problems in the five NAEP content areas. Eighth graders performing at the proficient level should be able to conjecture, defend their ideas, and give supporting examples. They should understand the connections between fractions, percents, decimals, and other mathematical topics such as algebra and functions. Students at this level are expected to have a thorough understanding of basic-level arithmetic operations -- an understanding sufficient for problem solving in practical situations. Quantity and spatial relationships in problem solving and reasoning should be familiar to them, and they should be able to convey underlying reasoning skills beyond the level of arithmetic. They should be able to compare and contrast mathematical ideas and generate their own examples. These students should make inferences from data and graphs, apply properties of informal geometry, and accurately use the tools of technology. Students at this level should understand the process of gathering and organizing data and be able to calculate, evaluate, and communicate results within the domain of statistics and probability.

Twelfth graders at 300 on the scale are within the Basic range and should demonstrate procedural and conceptual knowledge in solving problems in the five NAEP areas. Twelfth grade students performing at the basic level should be able to use

estimation to verify solutions and determine the reasonableness of results as applied to real-world problems. They are expected to use algebraic and geometric reasoning strategies to solve problems. Twelfth graders performing at the basic level should recognize relationships presented in verbal, algebraic, tabular, and graphical forms; and demonstrate knowledge of geometric relationships and corresponding measurement skills. They should be able to apply statistical reasoning in the organizations and display of data and in reading tables and graphs. They also should be able to generalize from patterns and examples in the areas of algebra, geometry, and statistics. At this level, they should use correct mathematical language and symbols to communicate mathematical relationships and reasoning processes, and use calculators appropriately to solve problems.

As can be seen from the two types of interpretations there are several differences.

- First, the description for 300 as an anchor point is exactly that. It describes what students can do who are at or near this point on the scale. In contrast, when using achievement levels, 300 falls into a range of scores, in the advanced range at grade 4, the proficient range at grade 8, and the basic range at grade 12.

- Second, the anchor level description is for students in all three grades (although only a handful of fourth graders were at or above 300). Students at this level are likely to be able to do the types of activities in math described at that point regardless of grade or age. In contrast, the achievement level descriptions are grade specific and are different at the three grades, reflecting the different expectations of students at the three grade levels.

- Third, and perhaps the most important difference, is the use of the words can and are able to in the anchor level description and the words should and are expected to in the achievement level descriptions. Since the anchor level description is based on an examination of items that discriminate at that level it is an empirical judgment about what students are able to do on the assessment in mathematics at level 300. In contrast, the achievement level descriptions are developed by a panel of experts to reflect what students at each level and at each grade should know and should be able to do and then mapped onto the scale. While the anchor level descriptions are derived primarily from an inspection of the actual items on the test, the achievement level operationalized descriptions are derived primarily from the test objectives. In other words, the anchor level descriptions are based on performance on the assessment and the achievement level descriptions are based on expectations about performance. These two types of descriptions are not interchangeable.

One issue that has arisen in the interpretation of the achievement levels is that readers tend to interpret them as statements of what students can do as opposed to what students should do at the various levels on the NAEP Scale. For example, based on the preliminary results of the review of press clippings from the 1990 release of NAEP data using achievement levels[48], the NAEP Technical Review Panel found that the vast majority of articles interpreted the achievement levels as statements of what students can do.

In order to determine better the extent to which students can do the behaviors mentioned in the achievement level descriptions, NCES sponsored a conference on March 3, 1993 to address the issue. Data from various studies were provided by ACT and the NAEP Technical Review Panel that attempted to determine the extent to which students "can do" the activities the achievement level descriptions indicate students "should do." Although data and arguments were provided from a variety of perspectives, the issue was not resolved. In the future, the issue needs to be more thoroughly addressed, and several ongoing studies will continue to examine the topic.

The achievement level standards were developed based on collective judgments about how students should perform. These descriptions were designed to be general statements about what students should be able to do at the various levels. Readers should be aware that additional evidence is needed regarding the mastery of the knowledge and skills implied in the achievement level descriptions. Because this process is developmental, modifications and improvements may be made in the future that could affect the reporting of results.

Knowledge and skills implied by each achievement level description represent expectations for student mathematical learning. It is important to consider, however, that the mathematical knowledge and skills contained in the achievement level descriptions are not intended to represent the universe of behaviors that might define a particular knowledge or skill, nor do they necessarily relate to any specific number of items in the NAEP assessment.

For example, some of the behaviors contained in the eighth grade Proficient (294) description are; "Students ... should understand the process of gathering and

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[48]Mary Lyn Bourque and Howard H. Garrison. *The Levels of Mathematic Achievement: Initial Performance Standards for the 1990 NAEP Mathematics Assessment.* (Washington, D.C.: National Assessment Governing Board, 1991).

organizing data and be able to calculate, evaluate, and communicate results within the domain of statistics and probability." The number and complexity of assessment exercises that could be written to define the universe of knowledge and skills related to probability and statistics is potentially immense, ranging from the simple to the complex.

The vehicle that is available to refine our focus on the segment of the domain represented in the description is the illustrative items. The illustrative items help the test user understand what is expected at each achievement level. Although only one illustrative item for each achievement level is provided in the Appendix, a larger set of items are available in other reports (e.g., see **NAEP 1992 Mathematics Report Card for the Nation and the States**).

At present, the best way that a test user has to understand the expected level of performance is to view each achievement level description, and the entire set of illustrative items associated with each level, in the aggregate. Viewing both the descriptions and the illustrative items in the aggregate will provide an overall picture of expected performance at each achievement level. As test development increases the size of the item pools over time, more items will become available for the test user so that a clearer picture of the expected levels of performance will emerge.

In summary, if we want to know what students actually can do at selected levels on the NAEP scale, we have to use the anchor level interpretations. If, on the other hand, we want to know what students should be able to do at certain levels on the scale, we have to use the achievement level interpretations.

Summary

As NAEP continues to explore ways to report its results more clearly and concisely to its audiences in the face of the growing complexity of the assessment and the demands placed upon it, issues related to the validity of the interpretations of those results will continue to arise. It has been clearly articulated that validity is related to the interpretations and use of the test scores and also related to the accumulation of evidence to support those interpretations.

Currently NAEP is introducing a new way of interpreting scores -- the achievement levels set by NAGB -- and in the future may consider other new ways of making NAEP data more useful and meaningful. The need for validity evidence to support

the interpretations presented by use of the achievement levels is evident, and Congress, through NCES, has provided for an independent evaluation to start the process. The National Academy of Education's evaluation of the Trial State Assessment is examining evidence from several studies that will help assess the validity of interpretations. As has been pointed out in this chapter, there have been times in past NAEP reports when interpretations were made using the anchor level descriptions that did not present evidence to support those interpretations. NCES has worked to remedy that situation and make the interpretations in NAEP as valid as possible using the anchor levels, and its goal is to make the same effort with the achievement levels, and any future methods of reporting and interpreting NAEP data.

APPENDIX

Exemplar Exercises For Scale Anchoring

The following paragraphs summarize performance at the four anchor levels, presenting one item for each level. A larger set of examples is usually shown to illustrate the range of difficulty represented within each level -- that is, from those answered correctly by approximately 65 percent of the students at the level to those that nearly all of the students performing at the level answered correctly.

Because the anchor analysis is based on students performing **at** particular levels, the results represent the lower boundaries of performance for the percentages of students who perform both **at** and **above** the levels, as in the way the results are presented in the reports. That is, items answered correctly by two-thirds or three-fourths of the students **at** a particular level, also were answered correctly by even more students **above** that level.

To demonstrate this point and provide a full picture of the anchoring process, the percentage correct results can be shown for each of the anchor levels for the illustrative items, (as is done below). However, the correct percent for the anchor levels represent performance only by those students at the designated anchor levels. The overall percentage correct tells how many students the total population answered the question correctly.

Level 200. In 1992, 72 percent of the fourth-grade students performed at or above Level 200, as did virtually all of the eighth and twelfth graders. This represented an increase from 1992 in the percentage of fourth graders attaining this level. Performance at Level 200 is typified by a range of questions that suggest some understanding of whole numbers, including addition and subtraction operations in the context of simple word problems (see the following item for an illustrative example).

There are 50 hamburgers to serve 38 children. If each child is to have at least one hamburger, at most how many of the children can have more than one?

A 6

B 12

C 26

D 38

Grade 4: 67% Correct Overall

Percent Correct for Anchor Levels			
200	250	300	350
59	84	95	--

Grade 8: 92% Correct Overall

Percent Correct for Anchor Levels			
200	250	300	350
77	93	97	97

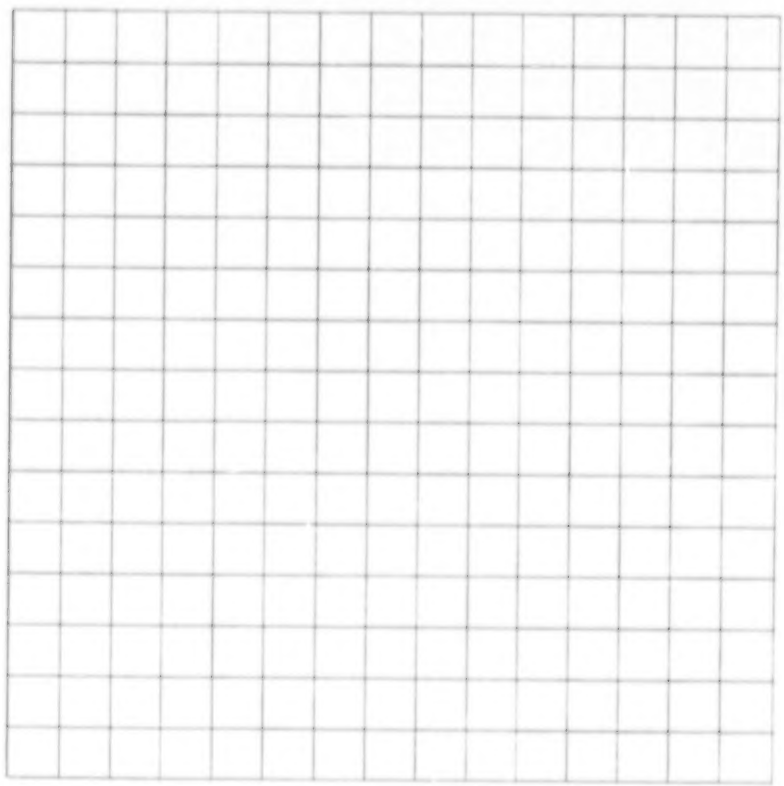
Fifty-nine percent of the fourth graders and 77 percent of the eighth graders at Level 200 answered this question correctly. Because more than 65 percent of the Level 200 students at one grade, but not at the other grade, answered this item correctly, it almost met the criteria for anchoring and represents the most difficult items likely to be answered correctly by students at Level 200. However, since 84 percent of the fourth graders and 93 percent of the eighth graders at Level 250 were able to answer this item correctly, many students with proficiency levels in the 225 to 250 range would be expected to be able to solve problems of this nature. As with the item mapping, however, it is important to remember that the p-values in relation to various levels of scale-score performance differ from the p-values for the total population. Taking the total population of students into consideration regardless of their scale-score estimate, the item was answered correctly by 67 percent of the fourth graders and 92 percent of the eighth graders.

Students performing at or above Level 200 also showed a familiarity with the attributes of length and weight, demonstrating relatively consistent success in recognizing the instruments used to measure these attributes and identifying appropriate units of measure. Their understanding of geometric figures and pattern sequences appeared to be very minimal.

Level 250. Students performing at or above Level 250 appeared to have extended their understanding of whole numbers from additive to multiplicative settings and were able to solve some two-step problems. In 1992, 17 percent of the fourth graders, two-thirds of the eighth graders, and 91 percent of the twelfth graders performed at or above this level. This represented an improvement for fourth graders, but essentially no change at grades 8 and 12.

Students performing at or above Level 250 also showed some growth in measurement, geometry, data analysis, and algebra compared to their counterparts at Level 200. For example, most could use a ruler to measure in centimeters, and close to two-thirds could draw a square given two corner points. They were developing an initial understanding of variables, as about 60 percent recognized that k could be replaced by infinitely many values in the expression k + 6. They also showed some beginning signs of being able to apply their understanding of the concept of area, as illustrated in the item presented below.

On the grid below, draw a rectangle with an area of 12 square units.



= 1 square unit

Grade 4: 42% Correct Overall

Percent Correct for Anchor Levels			
200	250	300	350
29	62	77	--

Grade 8: 66% Correct Overall

Percent Correct for Anchor Levels			
200	250	300	350
29	59	86	99

This grid item is an example of an item that almost anchored and because of its characteristics represents an emerging capability rather than solid understanding for students at this level. About 60 percent of the Level 250-students at both grades 4 and 8 provided a correct drawing, which is somewhat shy of the criteria (65 percent or more).

However, 30 percent fewer of the Level 200-students answered this item correctly (29 percent at both grade levels). Thus, Level 250-students were more likely to answer this question correctly than their counterparts at Level 200, and looking at the progression to Level 300, this item would be likely to be answered by most students who performed somewhat above Level 250.

Level 300. Students performing at or above Level 300 showed knowledge of a broader range of mathematical concepts and procedures. For example, many could solve multi-step problems. They also were developing some familiarity with geometric and statistical properties, and could perform simple manipulations involving algebraic expressions.

One-fifth of the eighth graders and half of the twelfth graders performed at or above Level 300 in 1992. This was an improvement compared to 1990, with 5 percent more students in both grades 8 and 12 attaining this proficiency level.

In the area of numbers and operations, students performing at or above Level 300 could do some computations and problems involving decimals, fractions, and percents. The following word problem was answered correctly by approximately 62 percent of the eighth graders and 72 percent of the twelfth graders performing at Level 300.

Ken bought a used car for $5,375. He had to pay an additional 15 percent of the purchase price to cover both sales tax and extra fees. Of the following, which is closest to the total amount Ken paid?

A $806

B $5,510

C $5,760

D $5,940

E $6,180

Did you use the calculator on this question?

Yes No

Grade 8: 40% Correct Overall

Percent Correct for Anchor Levels			
200	250	300	350
16	22	62	90

Grade 12: 69% Correct Overall

Percent Correct for Anchor Levels			
200	250	300	350
--	43	72	97

Level 350. Compared to their classmates at Level 300, students performing at or above Level 350 were able to demonstrate some understanding of specialized mathematical content. However, essentially the same proportions of students attained

Level 350 in 1992 as did in 1990 -- 1 percent of the eighth graders and 6 percent of the twelfth graders. It should also be noted that approximately 10 to 14 percent of the twelfth graders had already dropped out of school before their senior year and did not participate in the assessment.[49]

Students performing at or above Level 350 demonstrated familiarity with geometry and algebra. For example, they had success solving problems involving exponents, linear equations, and graphs of functions. Most could find the area of a trapezoid and use rectangular coordinates. For example, even though only 32% of the 12th graders solved the following problem correctly, 79% of those at level 350 determined the answer.

In the xy-plane, a line parallel to the x-axis intersects the y-axis at the point $(0, 4)$. This line also intersects a circle in two points. The circle has a radius of 5 and its center is at the origin. What are the coordinates of the two points of intersection?

A $(1, 2)$ and $(2, 1)$

B $(2, 1)$ and $(2, -1)$

C $(3, 4)$ and $(3, -4)$

D $(3, 4)$ and $(-3, 4)$

E $(5, 0)$ and $(-5, 0)$

Did you use the calculator on this question?

Yes No

Grade 12: 32% Correct Overall

Percent Correct for Anchor Levels

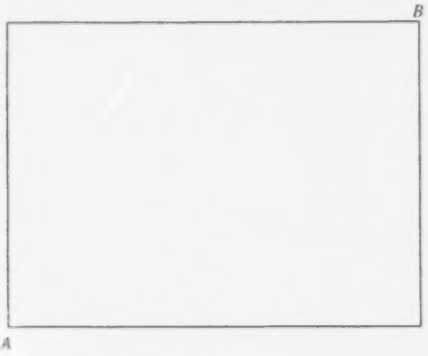
200	250	300	350
--	16	19	79

[49] *The Condition of Education 1990: Volume I*, Lawrence T. Ogle and Nabeel Alsalam, editors (Washington, DC: National Center for Education Statistics, U.S. Government Printing Office, 1990).

To reinforce an understanding of techniques that investigate p-values in relation to scale level, the following discussion uses examples from the anchor data. For example, 20 percent of the eighth graders and 50 percent of the twelfth graders performed at or above Level 300 on the mathematics scale. The item requiring students to compute a 15 percent addition to the cost of a car for tax and fees was answered correctly by 62 and 72 percent of the eighth and twelfth graders performing at Level 300, respectively. Thus, students performing at Level 300 would have approximately a two-thirds probability of answering this type of question correctly. Students at higher levels on the scale would have a higher probability of responding correctly (e.g., more than 90 percent at Level 350), and students at lower levels on the scale would have a lower probability (e.g., about 25 percent at Level 250). In actuality, when the total populations were considered regardless of scale level, 40 percent of the eighth graders and 69 percent of the twelfth graders responded correctly. The scale and anchor interpretations help describe what better and poorer students know and can do, but the overall percentages correct (p-values) for each item indicate the likelihood of success across the total population.

Exemplar Items For Achievement Levels

Grade 4, Basic 211. At Grade 4 the percentage of students at or above the 3 achievement levels rose from 1990 to 1992. The greatest improvements were seen at the Basic level, from 54% to 61%. This means that nearly two-thirds of all fourth graders should be able to perform simple computations with whole numbers and solve simple real-world problems in all the NAEP content areas. Additionally, of these same fourth graders more should be able to use four-function calculators and other manipulatives than they were in 1990. At the Basic level, for example, 64% of fourth-graders were able to measure the side of a rectangle to the nearest centimeter.



Use your centimeter ruler to make the following measurements to the nearest centimeter.

What is the length in centimeters of one of the longer sides of the rectangle?

Answer: _____

Grade 4: 52% Correct Overall

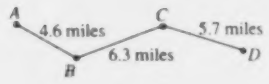
Percent Correct for Achievement Levels

Basic	Proficient	Advanced
64	92	99

It should be noted that the overall percent correct for the exemplar items represents the percentage of students in the fourth grade population who correctly responded to the item. However, the percentages at the Basic, Proficient, and Advanced levels represent only the percentages of students in those achievement level regions who were successful on the item.

Grade 4, Proficient 248. There were more modest improvements reported at the Proficient and Advanced levels (13% to 18% and 1% to 2% respectively). More fourth graders in 1992 should have an understanding of decimals and fractions and can employ problem-solving strategies than in 1990. For example, at the Proficient level, 54% of

students were able to estimate distance to the nearest mile given actual distances in decimal values.



Carol wanted to estimate the distance from A to D along the path shown on the map above. She correctly rounded each of the given distances to the nearest mile and then added them. Which of the following sums could be hers?

A 4 + 6 + 5 = 15

B 5 + 6 + 5 = 16

C 5 + 6 + 6 = 17

D 5 + 7 + 6 = 18

Grade 4: 25% Correct Overall

Percent Correct for Achievement Levels		
Basic	Proficient	Advanced
19	54	97

Grade 4, Advanced 280. At the Advanced level 59% of those students scored at the "satisfactory" or "extended" response levels on the extended constructed-response exemplar item.

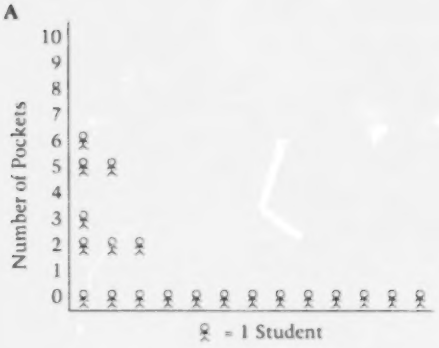
Grade 4: 10% Satisfactory or Extended Overall

Percent Satisfactory or Better for Achievement Levels		
Basic	Proficient	Advanced
8	29	59

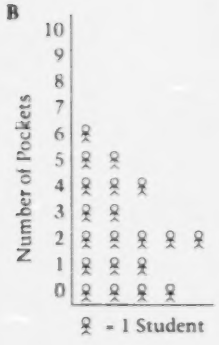
Think carefully about the following question. Write a complete answer. You may use drawings, words, and numbers to explain your answer. Be sure to show all of your work.

There are 20 students in Mr. Pang's class. On Tuesday most of the students in the class said they had pockets in the clothes they were wearing.

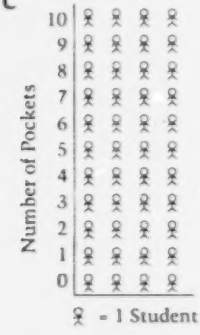
A



B



C

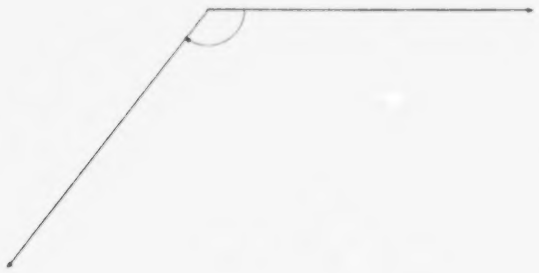


Which of the graphs most likely shows the number of pockets that each child had? _____

Explain why you chose that graph.

Explain why you did not choose the other graphs.

Grade 8, Basic 256. At grade 8, similar improvements from 1990 to 1992 were observed. At the Basic level, the percentage of students increased from 58% in 1990 to 63% in 1992. This means that students should be more likely to complete problems correctly when using diagrams, charts, and graphs. Greater percentages of students should be able also to use simple algebraic concepts and informal principles of geometry to solve problems. For example, 37% of eighth grade Basic students can use a protractor to find the degree measure of an angle.



Grade 8: 35% Correct Overall

Percent Correct for Achievement Levels

Basic	Proficient	Advanced
37	62	81

Use your protractor to find the degree measure of the angle shown above.

Answer: _____

Grade 8, Proficient 294. About one-fourth of the eighth graders are performing at the Proficient level in 1992 as opposed to one-fifth in 1990. In terms of the NAEP content this means that more students should have an understanding of the relationships between fractions, percents, and decimals, for example, as well as practical problem-solving ability. As an example, 73% of Proficient students can provide arguments for why multiplying another number by 6 could result in an answer either larger or smaller than the original number.

Tracy said, "I can multiply 6 by another number and get an answer that is smaller than 6."

Pat said, "No, you can't. Multiplying 6 by another number always makes the answer 6 or larger."

Who is correct? Give a reason for your answer.

_____

_____

_____

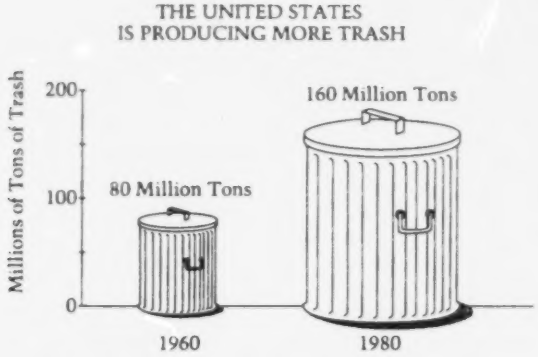
Did you use the calculator on this question?

Yes No

Grade 8: 48% Correct Overall

Percent Correct for Achievement Levels		
Basic	Proficient	Advanced
54	73	82

Grade 8, Advanced 331. The percentage of students performing at the Advanced level in grade 8 increased from 2 percent to 4 percent from 1990 to 1992. These students should be able to use abstract thinking and can use mathematical rules to generalize and synthesize mathematical concepts and principles. An example of Advanced performance is found in the following exemplar item where 42% of Advanced students were able to explain why a two-dimensional pictograph incorrectly represents a change in a one-dimensional variable.



The pictograph shown above is misleading. Explain why.

Answer: _____

_____

_____

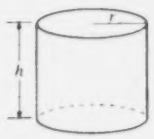
_____

Grade 8: 8% Correct Overall

Percent Correct for Achievement Levels		
Basic	Proficient	Advanced
7	16	42

Improvements at grade 12 were noted at the Basic and Proficient levels, but not at the Advanced level. For example, 64% and 16 % of students performed at the Basic and Proficient levels respectively in 1992, as opposed to 59% and 13% in 1990, while the Advanced level remained at 2% for both assessment years.

Grade 12, Basic 287. For the Basic twelfth grader this means that more students should be able to demonstrate procedural and conceptual knowledge in solving problems in all five NAEP content areas. For example, 83% of Basic students can calculate the volume of a circular cylinder given the formula, the radius, and the height.



Grade 12: 68% Correct Overall

Percent Correct for Achievement Levels		
Basic	Proficient	Advanced
83	98	99

The volume V of a right circular cylinder like the one in the figure above is given by the formula $V = \pi r^2 h$. In terms of π, what is the volume of a cylinder with radius $r = 4$ and height $h = 10$?

A 18π

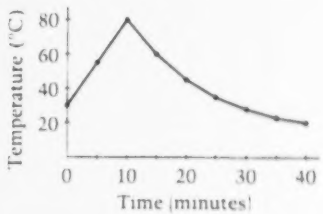
B 26π

C 80π

D 160π

E $1,600\pi$

Grade 12, Proficient 334. Proficient twelfth graders should be able to demonstrate an understanding of algebraic, statistical, geometric, and spatial reasoning in solving complex problems. They should also be able to judge and defend the reasonableness of answers to real-world problems such as the one shown in the exemplar item below. Ninety-seven percent of students performing at the Proficient level were able to correctly answer this question.



Grade 12: 74% Correct Overall

Percent Correct for Achievement Levels		
Basic	Proficient	Advanced
83	97	98

The graph above best conveys information about which of the following situations over a 40-minute period of time?

A Oven temperature while a cake is being baked

B Temperature of water that is heated on a stove, then removed and allowed to cool

C Ocean temperature in February along the coast of Maine

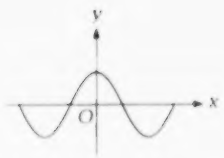
D Body temperature of a person with a cold

E Temperature on a July day in Chicago

Did you use the calculator on this question?

Yes No

Grade 12, Advanced 366. A small percentage (2%) of twelfth graders are able to perform at the Advanced level. This means that these students, for example, understand the function concept and should be able to compare and apply the numeric, algebraic, and graphical properties of functions. These students can successfully respond to questions like the following exemplar, where 92% answered this item correctly in 1992.

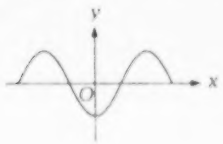


Grade 12: 20% Correct Overall

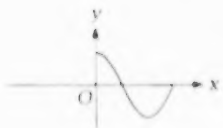
Percent Correct for Achievement Levels		
Basic	Proficient	Advanced
13	57	92

The figure above shows the graph of $y = f(x)$. Which of the following could be the graph of $y = |f(x)|$?

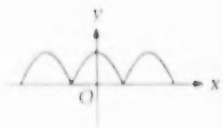
A



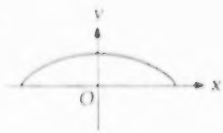
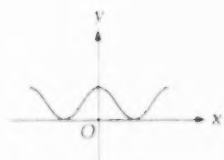
B



C



D



E